Variation Characteristics Of Different Types And Grades of Daily Precipitation In Tarim Basin

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Abstract

Recently, climate change has attracted many researchers worldwide, among which the analysis of different levels of precipitation changes is essential. In this study, we analyzed the spatial and temporal variations in the precipitation amount, precipitation days, precipitation intensity, and contribution rates in the Tarim Basin (TB) from 1961–2019. Our results demonstrate that the annual mean rainstorm, trace amounts of snow, and light snow exhibit downward trends, while all the other precipitation types increase. Both rainfall and snowfall were mainly concentrated in the western mountainous region. Rainstorms in the eastern parts of the TB were significantly higher than those in the western parts. Heavy rainstorm intensity is mainly concentrated on the southern slope of the Tianshan Mountains. The spatial distribution of trace amounts of snow, light snow, and moderate snow intensities has no prominent regional distribution characteristics. Heavy snow is mainly concentrated in the northern parts of the TB, whereas snowstorms are mainly concentrated in the western parts of the TB. Heavy snowstorms occur at a few stations in western mountainous areas. The relative contribution to total precipitation is the largest for rainfall, the second largest for snowfall, and the smallest for rain and snow. In the TB, the contribution of light rain/light drizzle to the total rainfall is the largest or smallest at 42-71 %/0.8-2.2 %. The contribution of light snow/trace amounts of snow to the total snowfall is the higest and lowest between 28.74~71.95 % and 1.60~13.61 %.

Introduction

Climate change is a prominent topic worldwide (Alexander et al., 2013; IPCC 2007), and precipitation is a primary driver of climate, which is important to society (Mishra et al. 2010). There is an important relationship between precipitation and precipitation frequency, precipitation intensity, and the number of precipitation days (Wang et al., 2015; Karl et al., 1998; Zhang et al., 2013). Precipitation not only exhibits obvious regional and seasonal differences, but the contribution of each grade of precipitation to the total precipitation is also regionally different (Gutowski et al. 2007). Hence, researchers have targeted East China (Bai et al. 2014), northeast China (Sun et al. 2007), eastern northwest (Zhou et al. 2016), eastern region (Ai et al. 2009), and other places that have different levels of precipitation for analysis.

Xinjiang is located in an arid inland region of China. The study of precipitation in this area has received attention, and the following consensus has been reached: Precipitation in Xinjiang is mainly concentrated in the summer (June–August) (Zhang et al. 1987), and its spatial differences in precipitation are obvious (Liu et al. 2003). Yang et al. (2003) analyzed the characteristics of extreme precipitation in Xinjiang during the past 40 years (1961–2000). They pointed out that there was no significant change in the intensity of extreme precipitation in Xinjiang, while the frequency of extreme precipitation was significant. In addition, in terms of different precipitation levels in Xinjiang, some studies have been conducted in the Yili region (Huang et al., 2015), Bole region (Xin et al., 2008; Zhang et al., 2008), and other regions. Studies have pointed out that precipitation has increased notably in the TB (Chen et al., 2005; Chen et al., 2013), but few studies have been conducted on precipitation changes in the TB (Li et al.2013).

Li et al. (Li et al. 2013) studied the characteristics of precipitation changes under different surface types in northwest China. Based on their research ideas, we conducted a more detailed research on the precipitation in this region with more data and more robust methods to obtain more detailed research results. It is essential to conduct such research work in the Taklimakan Desert and its surrounding areas for disaster mitigation, understanding local circulation, and providing a scientific basis for planning sustainable development in the Tarim Basin (TB). Above all, this understanding will provide a sound basis for climate forecasting in the future. The main aims of this study are: (1) to discuss the spatiotemporal distributions of precipitation during 1961–2019 in the TB; (2) to analyze the precipitation intensity during 1961–2019 at different levels of precipitation; and (3) to analyze the contribution rate during 1961–2019 at different levels of precipitation in the study area.

Materials And Methods

2.1 Study area

The TB (Fig. 1) is located in southern Xinjiang, the largest inland basin in China between the Tianshan, Kunlun, and Altun Mountains. It is approximately 1,500 km in width and 600 km in length, with an area of more than 53×104 km^2, and the altitude ranges from 800 to 1,300 m. The basin has little precipitation and high evaporation. Therefore, it has a typical continental arid climate. The Taklamakan Desert, located at the center of the TB, is approximately 1000 km in length and 400 km in width. It is the largest desert in China, with an area of approximately 337,600 km^2. The oases in the study area are distributed at the edge of the Taklamakan Desert, where they lay along river systems (Chen et al., 2017).

2.2 Data

We used ground-based precipitation data from 39 weather stations distributed within and around the Taklimakan Desert between 1961–2019. The data were provided by the Xinjiang Meteorological Administration, which had undergone strict quality control before it was released. Records from 39 stations were obtained between 1961 and 2019, with three additional stations from January 1966 to December 2019. Records of Tazhong ranged from July 1996 to December 2019, while records of Bachu ranged from January 1961 to March 1969 and October 1969 to December 2019. Data were collected at Maigaiti from January 1961 to July 1969 and November 1969 to December 2019. The records of the Tazhong weather station covered the shortest period.

2.3 Methods

2.3.1 Classification of precipitation levels

According to the “Classification Standard for Precipitation Intensity Classification” issued by Xinjiang Meteorological Administration, rainfall can be divided into light drizzle, light rain, moderate rain, heavy rain, rainstorm, heavy rainstorm, and extremely heavy rainstorm. Snowfall values can be divided into trace amounts of snow, light snow, moderate snow, heavy snow, snowstorms, heavy snowstorms, and extremely heavy snowstorms. Days with precipitation no less than 0.1 mm are defined as precipitation days. Table 1 illustrates the TB precipitation of different grades over the last 55 years.

Table 1
Classification of precipitation levels in TB

Type of rainfall day	24h rainfall division standard / mm	Type of snowfall day	24h snowfall division standard / mm
total rainfall	≥ 0.1	total snowfall	≥ 0.1
light drizzle	0.2 ≥ rainfall > 0.0	trace amounts of snow	0.2 ≥ snowfall > 0.0
light rain	6.0 ≥ rainfall ≥ 0.3	light snow	3.0 ≥ snowfall ≥ 0.3
moderate rain	12.0 ≥ rainfall ≥ 6.1	moderate snow	6.0 ≥ snowfall ≥ 3.1
heavy rain	24.0 ≥ rainfall ≥ 12.1	heavy snow	12.0 ≥ snowfall ≥ 6.1
Rainstorm	48.0 ≥ rainfall ≥ 24.1	snowstorm	24.0 ≥ snowfall ≥ 12.1
Heavy rainstorm	96.0 ≥ rainfall ≥ 48.1	heavy Snowstorm	48.0 ≥ snowfall ≥ 24.1
extremely heavy rainstorm	> 96.0	extremely heavy snowstorm	> 48.0

2.3.2 Precipitation intensity and contribution rate

From the precipitation days and precipitation of different grades, the precipitation intensity (PI) of different grades can be calculated. PI is equal to the ratio of precipitation in the corresponding precipitation period to precipitation days in the same period (Guo et al. 2010). The ratio (%) of the precipitation of each grade (day) to the total precipitation (day) indicates the contribution rate of each grade of precipitation (day) to the total precipitation (day) (Wang et al., 2015).

Results

3.1 Spatial distribution characteristics of different types of precipitation

The terrain of the TB is complex and diverse, and there are obvious spatial distributions in the precipitation (Xin et al. 2008). We present below an analysis of the spatial distribution characteristics of annual mean precipitation (AMP), annual mean rainfall (AMR), and annual mean snowfall (AMS) to reveal the regional characteristics of different types of precipitation in the TB. Figure 2 shows the spatial distribution of AMP, AMR, and AMS in the TB. AMP in the TB as a whole presents a spatial distribution pattern that is more in the northwest and less in the southeast (Fig. 2a). Also affected by the topography of the Tianshan Mountains, Kunlun Mountains, and Pamir plateau, AMP in the mountain areas is relatively frequent and generally above 70 mm; in the southern and eastern regions, precipitation is below

40 mm. In the total area, the lowest value appeared in Qiemo (25.70 mm), while the highest value was observed in Tuergate (260.27 mm), which is the driest area in China. The distribution of AMR (Fig. 2b) is roughly the same as the distribution of AMP, decreasing from northwest to southeast. High-value areas appear in the Tuergate, Wuqia, Aheqi, and Tashikuergan regions (> 40 mm), and low-value areas appear in the eastern parts of the TB. In the total area, the lowest value appeared in Ruoqiang (18.85 mm), while the highest value was observed in Aheqi (158.13 mm), and the overall appearance decreased from northwest to southeast. The spatial distribution of AMS in the TB was maintained at 0.36 ~ 133.65 mm, with a high-value area (> 16 mm) in the mountains, decreasing from northwest to southeast, presenting a spatial distribution of "more in the mountains and less in the desert and east parts of the desert" (Fig. 2c).

The above analysis shows that due to the influence of topography, geography, climate, and other factors, the spatial distribution of AMP, AMR, and AMS in the TB is significantly different. This difference presents a spatial distribution of "more in the northwest and less in the southeast." Due to the scarcity of precipitation, the TB is the driest region in China, and the precipitation variability is large.

3.2 Trend variation of precipitation

3.2.1 Spatial distribution trend of annual average precipitation, rainfall, and snowfall

There was a considerable spatial variability in the increasing rate of annual mean precipitation, rainfall, and snowfall range from 1.29 mm/10a to 24.53/10a, 0.66 mm/10a to 26.33/10a, and 0.11 mm/10a to 10.44/10a (Fig. 3), respectively, with all the stations showing an increasing trend. The lowest increasing rates were found at Qiemo, Tieganlike, and Shache, whereas the highest values were found at Aheqi, Aheqi, and Tuergate. These analyses indicated that there seemed to be a clear spatial pattern: the increasing rates of high precipitation, rainfall, and snowfall areas were mainly concentrated in the western mountain region, followed by the western oasis, and the low values in the eastern regions and small oases near the desert. The above-mentioned significant increase rate of annual mean precipitation also shows that the closer to the mountain, or the larger the mountain, the greater the tendency for annual mean precipitation, rainfall, and snowfall to increase.

3.2.2 Linear trend of annual average precipitation, rainfall, and snowfall

We evaluated the trend variation in annual mean precipitation over the TB (Fig. 4). There was an upward trend in the annual mean precipitation, rainfall, light drizzle, light rain, moderate rain, heavy rain, heavy rainstorm, snowfall, moderate snow, heavy snow, snowstorm, and heavy snowstorm; with rates of 6.95, 6.10, 0.004, 2.19, 0.95, 0.62, 3.23, 0.86, 0.34, 0.09, 0.96, and 0.32 mm/10a, respectively. The annual mean rainstorm, trace amounts of snow, and light snow demonstrate downward trends with rates of 0.34, 0.02, and 0.02 mm/10a, respectively. The increasing trend rate of annual mean precipitation is highest, and the increasing rate differences between annual mean precipitation and annual mean rainfall are relatively small, indicating that rainfall dominates in total precipitation trends.

3.3 Precipitation intensity

3.3.1 Spatial distribution intensity of precipitation, rainfall, snowfall, rain and snow

There was also a substantial spatial variability in the total precipitation, rainfall, snowfall, and rain and snow intensities in the TB range from 1.63 mm/d to 3.37 mm/d, 1.64 mm/d to 2.95 mm/d, 0.57 mm/d to 2.22 mm/d, and 0.44 mm/d to 0.53 mm/d (Fig. 5), respectively. The spatial distribution of the total precipitation intensity increases from the center of the desert to the mountain regions. The large value areas are located in Aheqi (> 3 mm/d), and small value areas appear in the center, southeastern, and northern parts of the desert (< 2 mm/d). In the total area, the lowest value appeared in the Akesu (1.63 mm/d), while the highest value appeared in Aheqi (3.37 mm/d) (Fig. 5a). The spatial distribution of the total rainfall intensity increases from the center of the desert to the mountain regions. The large value areas are located in Aheqi, Wuqia, Cele (> 2.5 mm/d), and a small value area appears in the center, northwest, and southeastern parts of the desert (< 2 mm/d). In the total area, the lowest value appeared in the Xinhe (1.64 mm/d), while the highest value appeared in Aheqi (2.95 mm/d) (Fig. 5b).

The spatial distribution of the total snowfall intensity increased from the east to the mountain regions. The large value areas are located in Atushi, Aheqi, Aketao, Wuqia, Kashi, Tuergate, and Yingjisha (> 1.5 mm/d), while the small value areas of Tazhong, Akesu, Kuerle, and Alaer appear in the center, northeastern, eastern, and southeastern parts of the desert (< 0.8). In the total area, the lowest value appeared in the Tazhong (0.57 mm/d), while the highest value was observed in Atushi (2.22 mm/d) (Fig. 5c).

The spatial distribution of rain and snow intensity increased from the southeast to the northwestern mountainous regions of the TB. In the total area, the lowest value appeared in Ruoqiang (0.44 mm/d), while the highest value was observed in Tuergate (0.53 mm/d (Fig. 5d). Therefore, the spatial distribution of total precipitation, rainfall, snowfall, and rain and snow intensity of various grades has obvious regional distribution and presents a spatial distribution pattern of “more in the mountain and less in the desert and eastern parts of the desert.”

3.3.2 Spatial distribution of different level of rainfall intensity

According to Fig. 6, the light drizzle, light rain, moderate rain, heavy rain, rainstorm, and heavy rainstorm intensities in the TB range from 0.13 to 0.15 mm/d, 1.28 to 1.90 mm/d, 7.81 to 8.75 mm/d, 14.45 to 18.45 mm/d, 31.3 to 35.1 mm/d, and 47.7 to 74.6 mm/d, respectively. The spatial distribution of light drizzle, light rain, moderate rain, and heavy rain intensities generally presents a similar spatial distribution pattern, where no apparent regional distribution characteristics are observed, with the highest values at Ruoqiang, Aheqi, Yutian, and Akesu, and the lowest values in Yanji, Tazhong, Tazhong, and Tazhong, respectively. The spatial distribution of rainstorm intensity demonstrates that the eastern parts of the study area are significantly higher than those of the western parts; Kuche, Shaya, and Xinhe are significantly higher than the surrounding areas. Heavy rainstorm intensity is mainly concentrated on the southern slope of the Tianshan Mountains.

3.3.3 Spatial distribution of different level of snowfall intensity

According to Fig. 7, the trace amounts of snow, light snow, moderate snow, heavy snow, snowstorm, and heavy snowstorm intensities in the TB range from 0.12 to 0.15 mm/d, 0.70 to 1.15 mm/d, 3.73 to 4.86

mm/d, 6.1 to 8.8 mm/d, 12.1 to 19.8 mm/d, and 24.5 to 32.8 mm/d, respectively.

Spatial distributions of trace amounts of snow, light snow, and moderate snow intensities present a similar spatial distribution pattern. There are no obvious regional distribution characteristics. The highest value is at Jiashi, Atushi, Awati, and the lowest value is at Pishan, Tieganlike, and Awati, respectively.

The spatial distribution of heavy snow intensity reveals that heavy snow intensity is mainly concentrated in the northern parts of the study area. The highest value is at Kepeng, and the lowest value is at Cele. Snowstorm intensity is mainly concentrated in the western parts of the TB; the highest value is at Yecheng, and the lowest value is at Alaer. Heavy snowstorm intensity is only distributed in a few stations in the western mountainous area; the highest value is at Wushi, and the lowest value is at Shaya.

3.4 Contribution of different levels of precipitation to total precipitation

To better understand the complex relationship between the precipitation of each grade and the total precipitation, we calculated the contribution rate of each grade of precipitation and precipitation days to the total precipitation and precipitation days, respectively.

3.4.1 Contribution of rainfall, snowfall, and rain and snow to total precipitation

Figure 8 depicts the spatial distribution of different types of precipitation contribution rates. In the TB, the contribution rate of small rainfall (Fig. 8a) was the largest, between 37.73 ~ 93.62 %. The highest value was at Tazhong, and the lowest value was at Tuergate, respectively; the eastern parts of the basin are slightly higher than the western parts. The contribution rate of snowfall (Fig. 8b) is slightly lower than rainfall, which is usually at 3.42 ~ 51.35 %; the highest value is at Tuergate, and the lowest value is at Tazhong, respectively. Tuergate is significantly higher than all other regions. The contribution rate of snowfall in other regions is between 3.42–22.11 %. High contribution rate areas are mainly concentrated in mountainous areas. The contribution rate of rain and snow (Fig. 8c) is different from that of rainfall and snowfall between 0.01 ~ 1.28 %, mainly concentrated on a few sites, such as Tasikuergan (1.28 %), Luntai (1.04 %), Akesu (0.85 %), and Luopu (0.66 %). The above analysis demonstrates that in the TB, the contribution rate of rainfall is the largest, the contribution rate of snowfall is second, and the contribution rate of rain and snow is the lowest.

3.4.2 Contribution of different levels of rainfall to total rainfall

Figure 9 demonstrates the spatial distribution of the different levels of the rainfall contribution rate. In the TB, the contribution rate of light rain (Fig. 9b) was the largest at 42.39 ~ 70.53 %. The highest value is at Tashikuergan, and the lowest value is at Aheqi. The southern slope of Tianshan Mountain is significantly higher than in the other areas. The contribution rate of the light drizzle is lowest at 0.77 ~ 2.20 %. The highest value is at Akesu, and the lowest value is at Aheqi, with areas of high contribution rate mainly concentrated in the northern areas. The spatial distribution of moderate rain, heavy rain, and rainstorm contribution rates presented a similar spatial distribution pattern, with the highest values at Hetian (42.74

%), Yutian (42.82 %), and Yuepuhu (23.18 %), and with the lowest values at Tazhong (24.17 %), Qiemo (13.79 %), and Tashikuergan (2.20 %), respectively. Mountain regions showed significantly higher values than those in other areas. The heavy rainstorm contribution rate ranged from 0.86–11.28 %; the highest value was at Ruoqiang (11.28 %), and the lowest value was at Tuergate (0.86 %). Areas with high contribution rates are mainly concentrated in the eastern parts of the study area.

3.4.3 Contribution of different levels of snowfall to total snowfall

Figure 10 shows the spatial distribution of the different levels of the snowfall contribution rate. In the TB, the contribution rate of light snow (Fig. 10a) is the largest between 28.74 ~ 71.95 %; the highest value is at Qiemo, and the lowest value is at Atushi. The southeastern region shows significantly higher values than those in other areas; the contribution rate of trace amounts of snow is between 1.60 ~ 13.61 %. The highest value is at Tazhong, and the lowest value is at Atushi, and the high contribution rate areas are mainly concentrated in the northeastern parts of the study area.

The spatial distribution of moderate snow contribution rate ranges from 10.59–42.25 %; the highest value is at Tazhong, and the lowest value is at Alaer. There are no obvious regional distribution characteristics; the spatial distribution of heavy snow and snowstorm contribution rates generally present a similar spatial distribution pattern, with the highest value at Tiegnlike (29.15 %) and Aheqi (17.96 %), and the lowest value at Cele (2.58 %) and Jiashi (2.71 %), respectively. High contribution rates were mainly concentrated in the northwestern parts of the study area. The heavy snowstorm contribution rate is mainly concentrated at several stations in the northwest, ranging from 1.91–8.75 %, with the highest value at Atusi and the lowest value at Aheqi.

Discussion

Affected by warming, precipitation in the TB has a large interannual and spatial variability. In this study, we analyzed the trends in a set of daily precipitation indices for the TB between 1961–2019. Changes in the daily amount and distribution of precipitation have important implications because agriculture and water supply are often limited by water availability in the study area, and heavy rainfall events constitute a major natural hazard in the region.

In the past 58 years, although the annual mean precipitation and precipitation days in the study area has increased, indicating a change in the precipitation intensity in the study area. Therefore, suitable water planting is still needed to vigorously develop water-saving agriculture, strengthen drought monitoring and early warning, strengthen emergency drought prevention and disaster avoidance technology, and improve agriculture in Northwest China to adapt to drought.

The spatial and temporal differences found in the evolution of precipitation indices have important implications for water management and risk assessment in the region. Thus, an increased precipitation is observed in the region, and increasing surface air temperatures can lead to an enhanced melting of snow and glaciers in the surrounding mountains of the TB, causing extreme runoff events such as floods (Peng et al. 2014). Climate change has resulted in an increase in the streamflow at the headwaters of the Tarim

River, but anthropogenic activities, such as over-depletion of the surface water, have resulted in a decrease in the streamflow at the lower reaches of the Tarim River (Chen et al. 2005).

Rainfall, snowfall, and rain and snow are the three important attributes of precipitation events. The three contain important information about the occurrence and development of precipitation. In-depth studies of these three attributes can significantly deepen the understanding of precipitation itself, the physical mechanism behind it, and the climate background. From a holistic perspective, rainfall, snowfall, and rain and snow amounts are not independent. If these three are separated and analyzed independently, although some important information about precipitation can be obtained, this information is still only based on a single feature of precipitation, frequency, or intensity and only contains information about a certain aspect of the precipitation event. It also does not contain the overall information of the rainfall, snowfall, rain, and snow events. Hence, it is impossible to grasp the characteristics of changes in precipitation types as a whole. If there is no significant change in precipitation in an area, but the intensity of rainfall increases and the frequency of extreme rainfall increases, the possibility of flooding increases. Therefore, it is necessary to study the in-depth changes for at least two attribute characteristics of rainfall events of different intensities, rainy days, and rain intensity from a systematic perspective.

The determination of different rainfall patterns and impact diagnosis rainfall includes process rainfall, convective rainfall, and topographic rainfall. Convective rainstorms are not only affected by natural factors but also by strong local human activities and urbanization (Ai et al. 2009). It can be seen that different rain patterns characterize different rainfall processes, and the physical processes and formation mechanisms behind them are also different. Therefore, the determination of different rain patterns in rainfall research is of great significance to the study of different rainfall intensities and their contribution to total rainfall.

This paper analyzes the spatial distribution characteristics of different levels of precipitation, precipitation days, precipitation intensity, and contribution rate in the TB without discussing its influencing factors. In addition, because of the vast area of the TB, the distribution of meteorological stations is scattered, especially, in the Bazhou area in the southeast, where the distribution of stations is sparse. Hence, the spatial distribution of the precipitation revealed is not detailed enough. In addition to topography, geography, and other factors, it is necessary to analyze the corresponding atmospheric circulation patterns when various levels of precipitation occur in the TB, especially, the corresponding weather system, which still needs to be studied further.

Conclusions

We investigated the spatiotemporal distribution of daily precipitation during 1961–2019. The spatial distribution of precipitation, time-series trends, intensity, and contribution rate were investigated using ground-based observation data.

In the study area, the spatial distribution of annual mean precipitation, rainfall, and snowfall is significantly different. It generally presents a spatial distribution that is more in the northwest and less in the southeast.

There is a clear spatial pattern of increasing precipitation rate; rainfall and snowfall areas are mainly concentrated in the western mountain region, followed by the western oasis, and the low values in the eastern regions and small oases near the desert. Annual mean precipitation shows that the closer to the mountain, the greater the tendency for annual mean precipitation, annual mean rainfall, and annual mean snowfall to increase. In the study area, annual mean rainstorms, trace amounts of snow, and light snow showed a downward trend, while all the other precipitation types showed an upward trend.

The spatial distribution of total precipitation, rainfall, snowfall, and rain and snow intensity of various grades has obvious regional distribution, presenting a spatial distribution pattern that is more in the mountain and less in the desert and eastern parts of the desert.

The spatial distribution of light drizzles, light rain, moderate rain, and heavy rain intensities presents a similar spatial distribution pattern, where there are no obvious regional distribution characteristics. The spatial distribution of rainstorm intensity shows that the eastern parts of the study area are significantly higher than those of the western parts. Heavy rainstorm intensity is mainly concentrated on the southern slope of the Tianshan Mountains.

The spatial distribution of trace amounts of snow, light snow, and moderate snow intensities exhibit a similar spatial distribution pattern with no obvious regional distribution characteristics. The spatial distribution of heavy snow intensity shows that heavy snow intensity is mainly concentrated in the northern parts of the study area; snowstorm intensity is mainly concentrated in the western parts of the TB; heavy snowstorm intensity is only distributed in a few stations in the western mountainous area.

The above analysis shows that in the TB, the contribution rate of rainfall is the largest, the contribution rate of snowfall is the second, and the contribution rate of rain and snow is the lowest. In the TB, the contribution rate of light rain to total rainfall was the largest between 42.39 ~ 70.53 %, and the light drizzle is the lowest between 0.77 ~ 2.20 %. The contribution rate of light snow to total snowfall is the largest at 28.74 ~ 71.95 %, and trace amounts of snow exist between 1.60 ~ 13.61 %.

Declarations

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Conflicts of Interest The authors declare no conflicts of interest.

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Figures

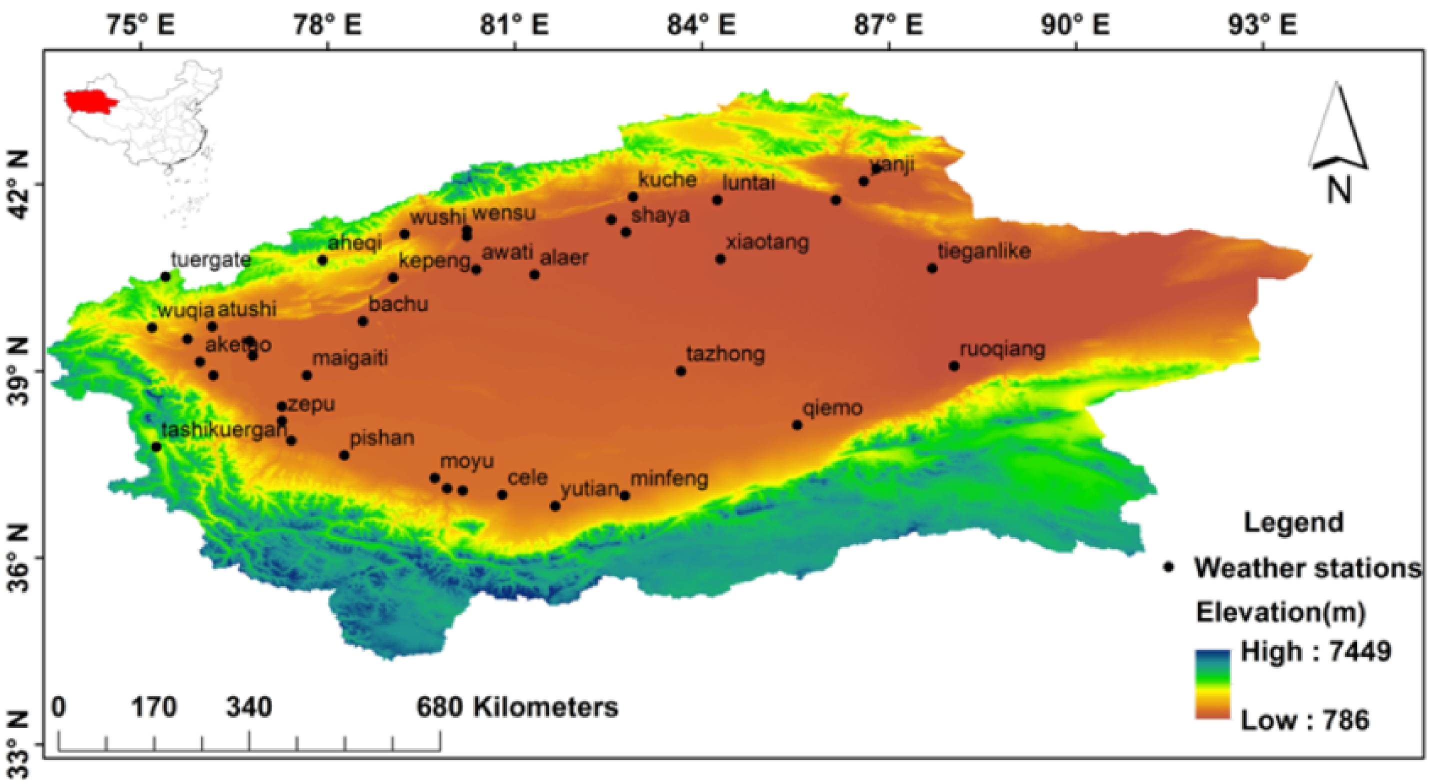

Figure 1

Locations of the meteorological stations in TB. The black dots represent stations in the TB Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

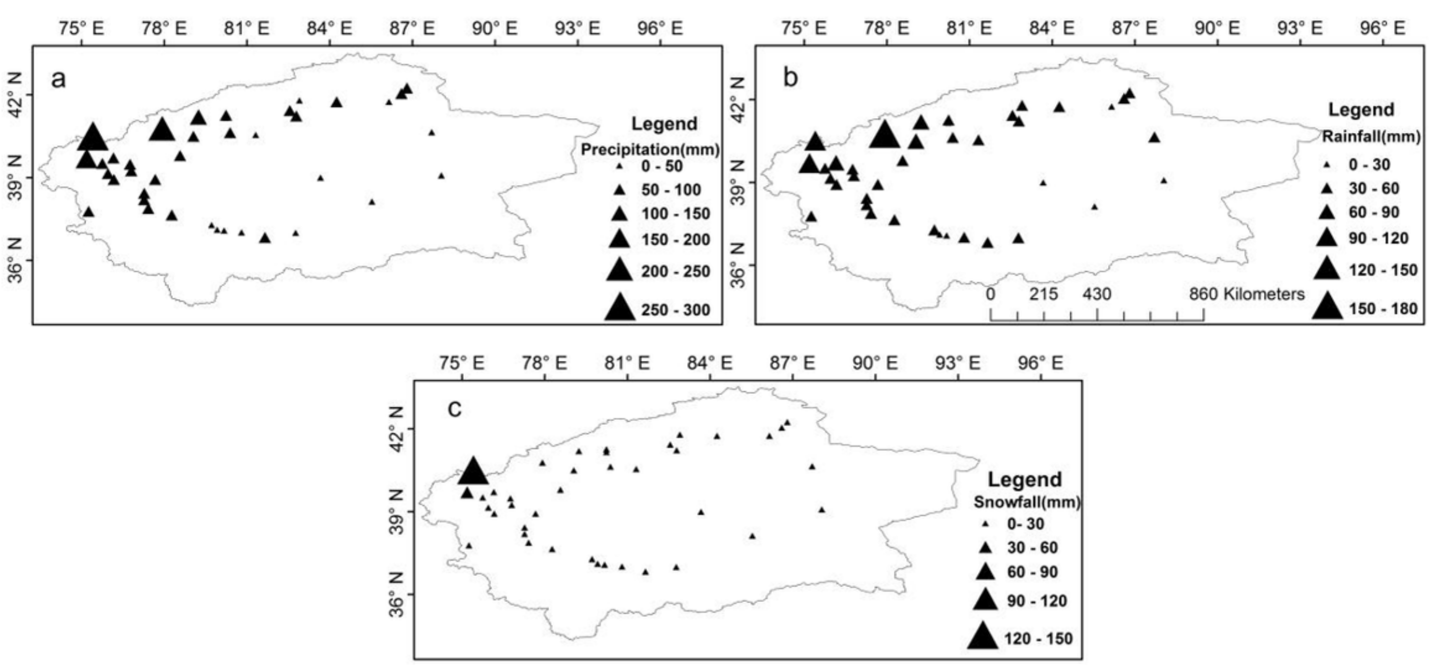

Figure 2

Spatial distribution of the climatologic annual mean precipitation (a), annual mean rainfall (b), and annual mean snowfall (c) in TB from 1961–2019 Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

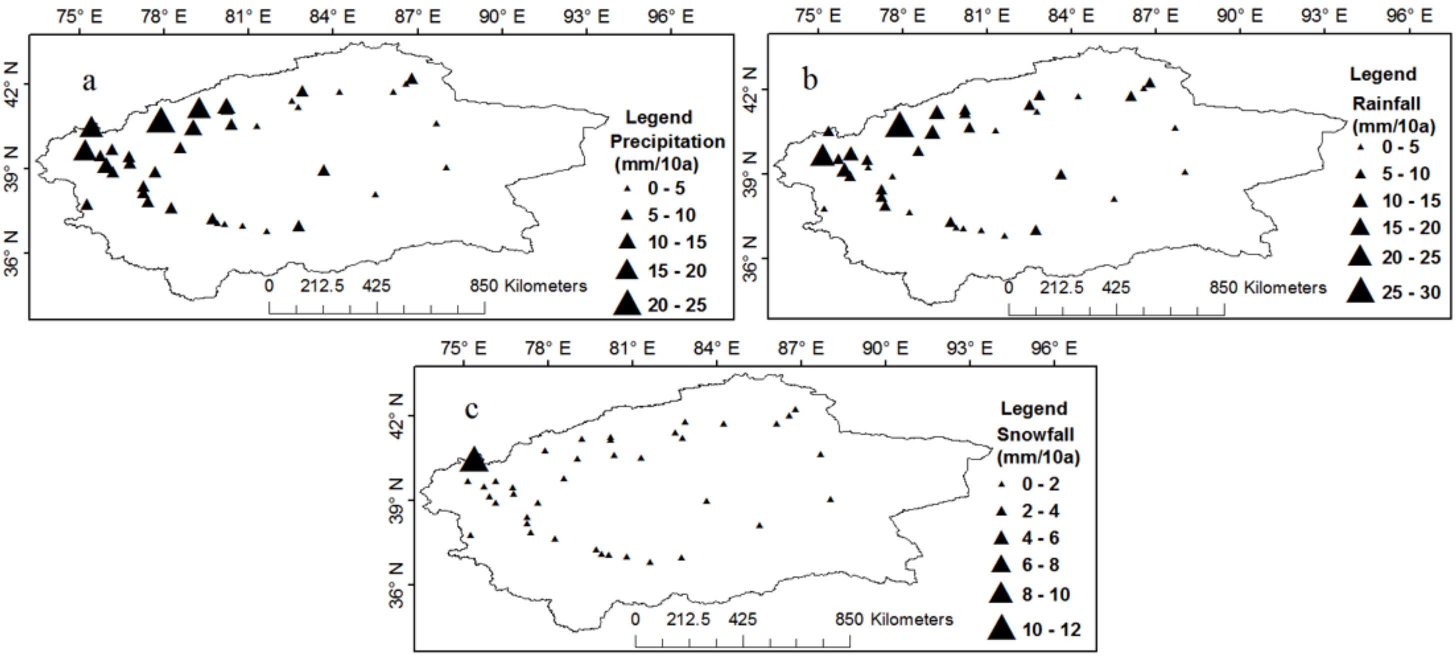

Figure 3

Trend distribution of the climatologic annual mean precipitation (a), rainfall (b), and snowfall (c) in TB from 1961–2019 Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

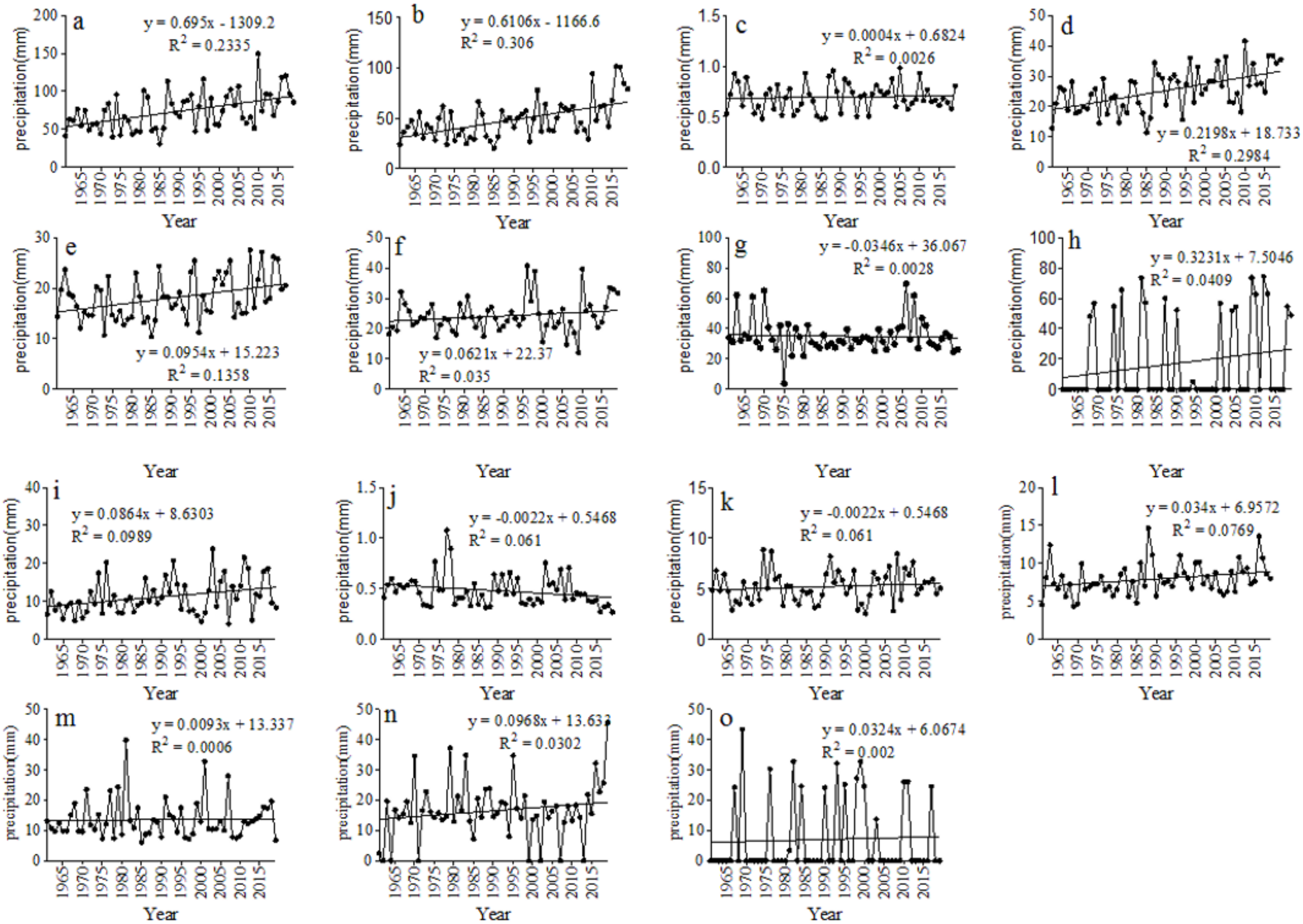

Figure 4

Trend variation of annual mean precipitation (a), rainfall (b), light drizzle (c), light rain (d), moderate rain (e), heavy rain (f), rainstorm (g), heavy rainstorm (h), snowfall (i), trace amounts of snow (j), light snow (k), moderate snow (l), heavy snow (m), snowstorm (n), and heavy snowstorm (o) over the TB during 1961–2019

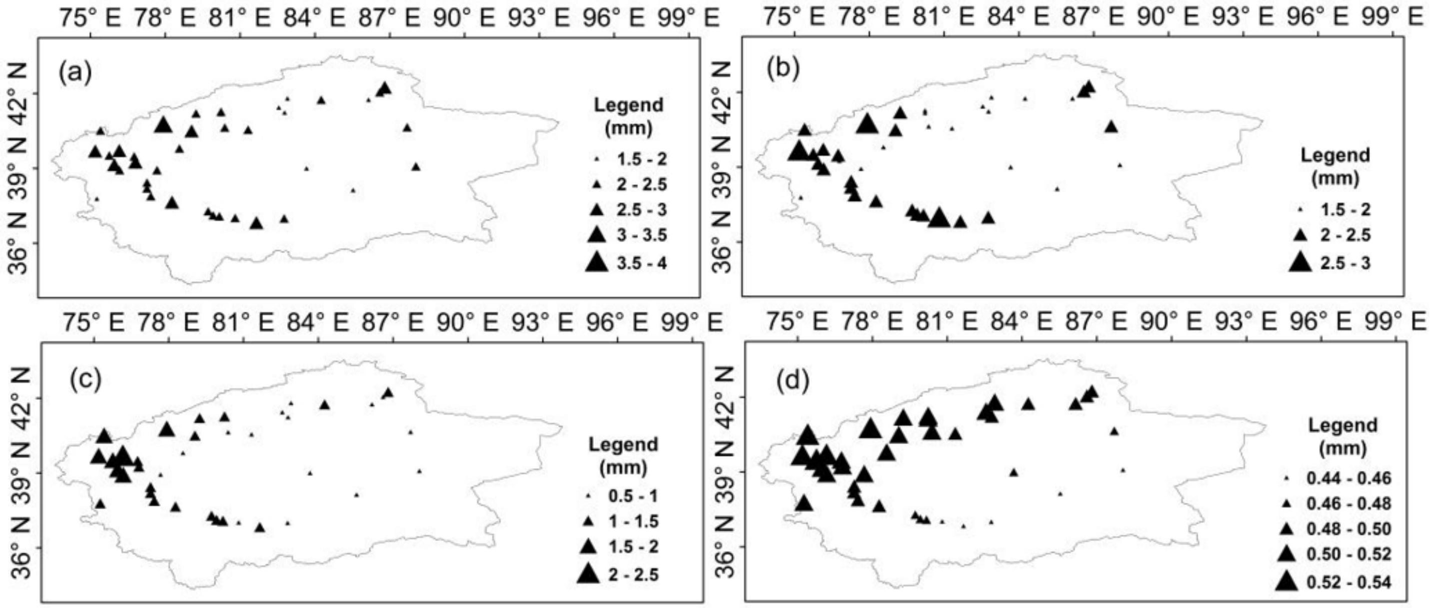

Figure 5

The spatial distribution of total precipitation (a), rainfall (b), snowfall (c), and rain and snow (d) intensity in the TB for the period 1961–2019 Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

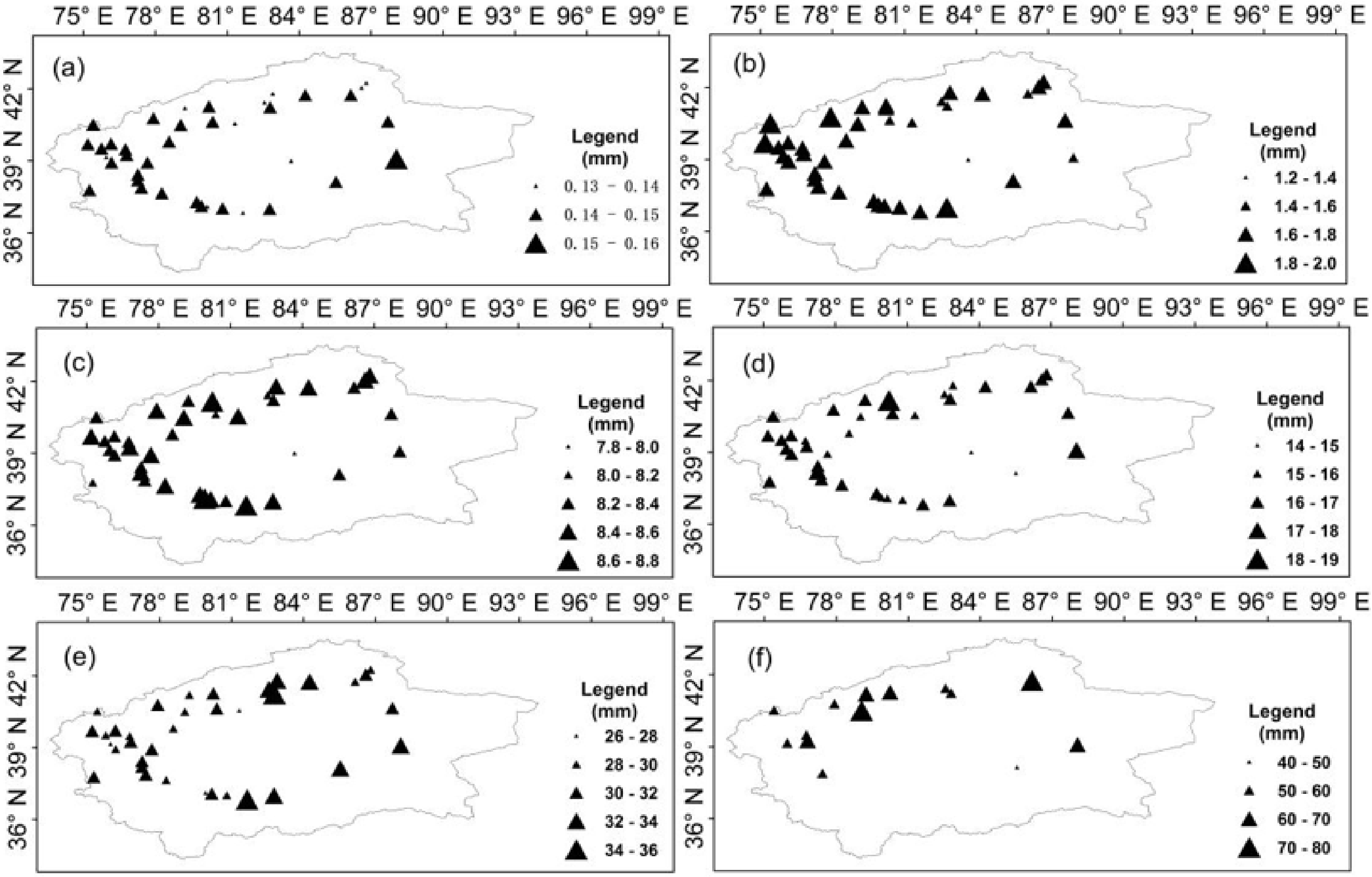

Figure 6

The spatial distribution of different levels of total rainfall intensities from 1961–2019, light drizzle (a), light rain (b), moderate rain (c), heavy rain (d), rainstorm (e), and heavy rainstorm (f) Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

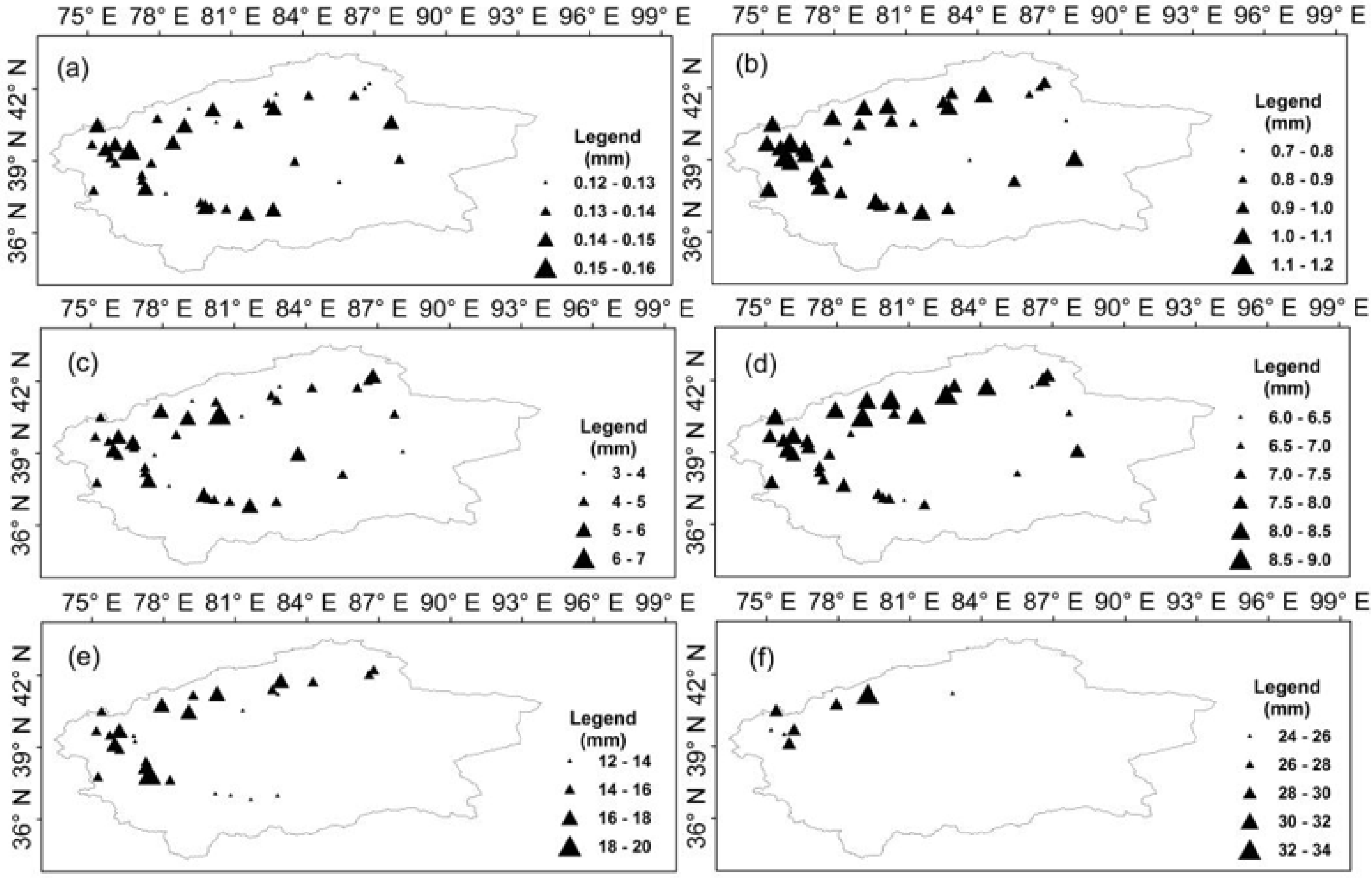

Figure 7

The spatial distribution of different levels of total snowfall intensities from 1961 to 2019trace amounts of snow (a)light snow (b)moderate snow(c)heavy snow (d) snowstorm (e) and heavy snowstorm (f) Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

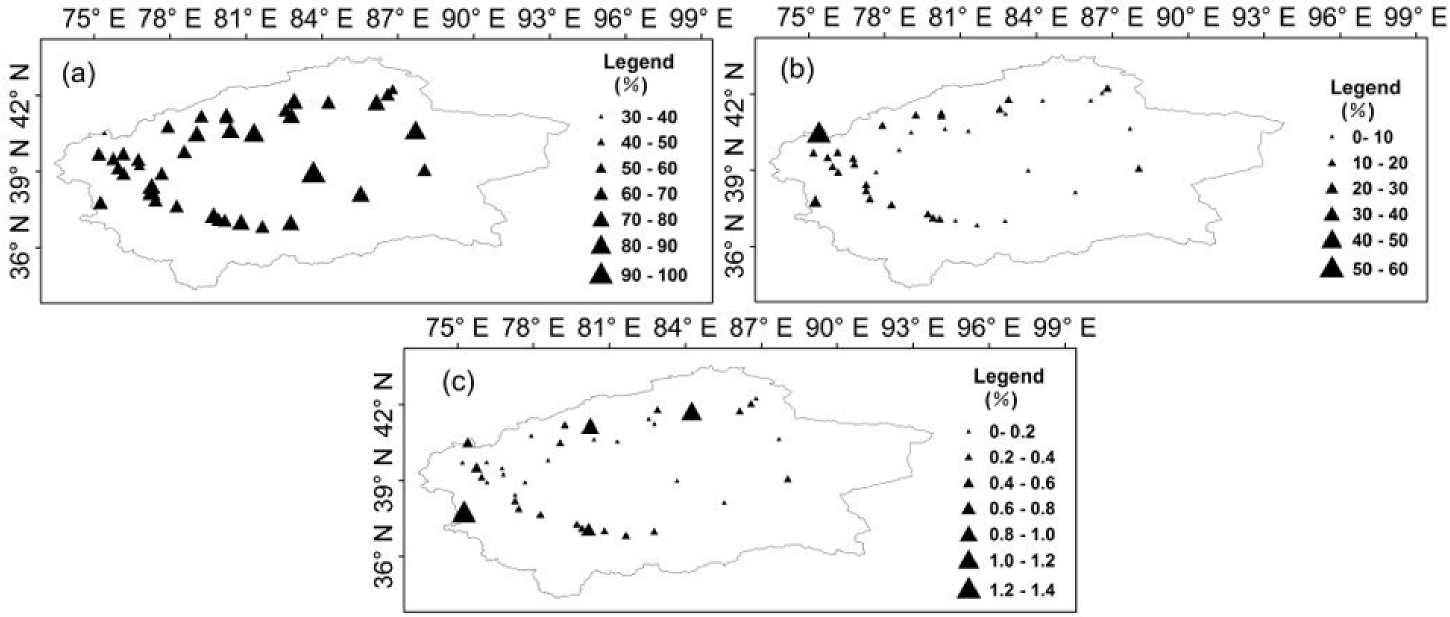

Figure 8

Contribution rate of rainfall (a), snowfall (b), and rain and snow (c) amount to total precipitation in the TB Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

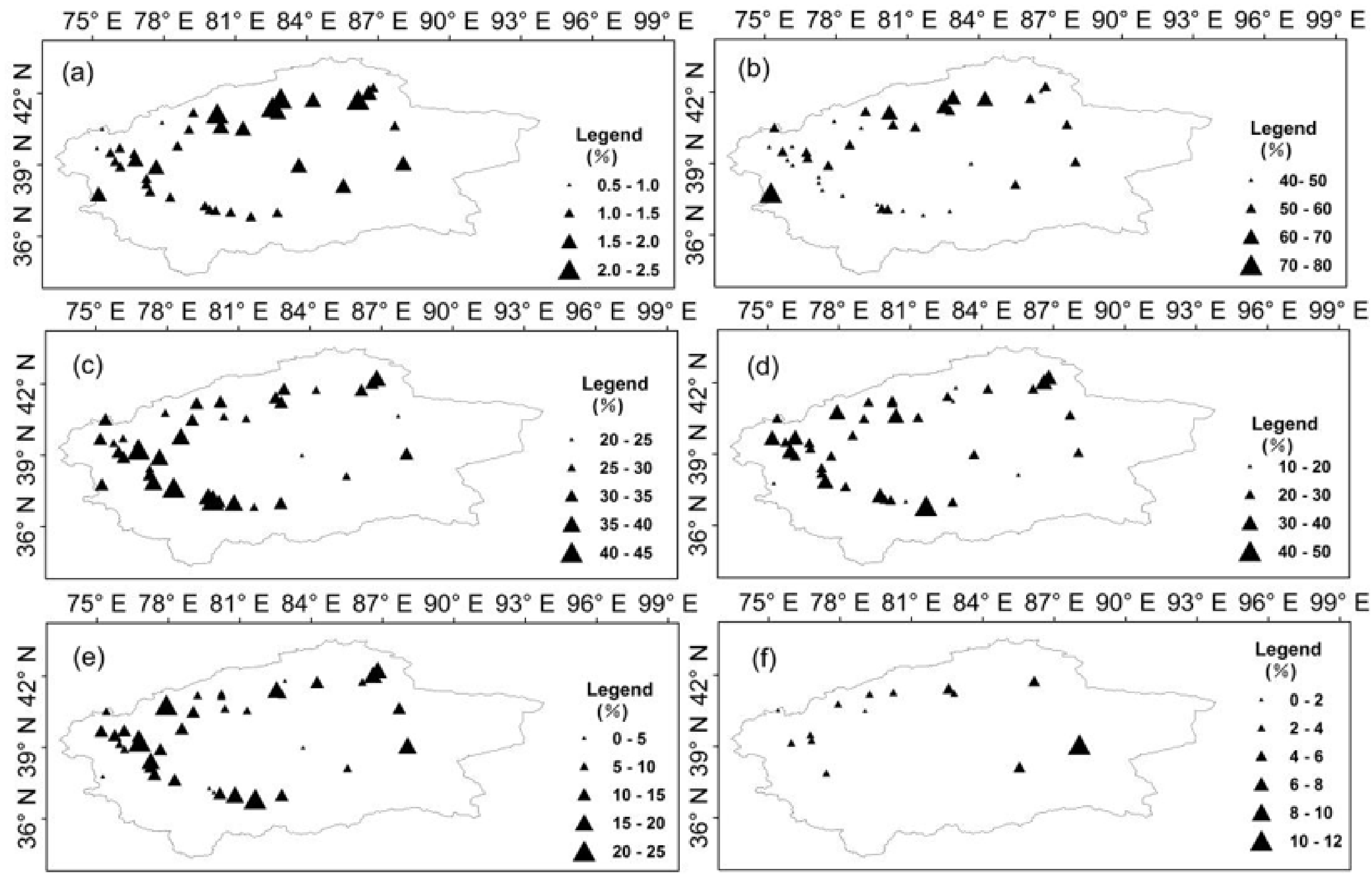

Figure 9

Contribution rate of light drizzle (a), light rain (b), moderate rain (c), heavy rain (d), rainstorm (e), and heavy rainstorm (f) to total rainfall in the TB Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

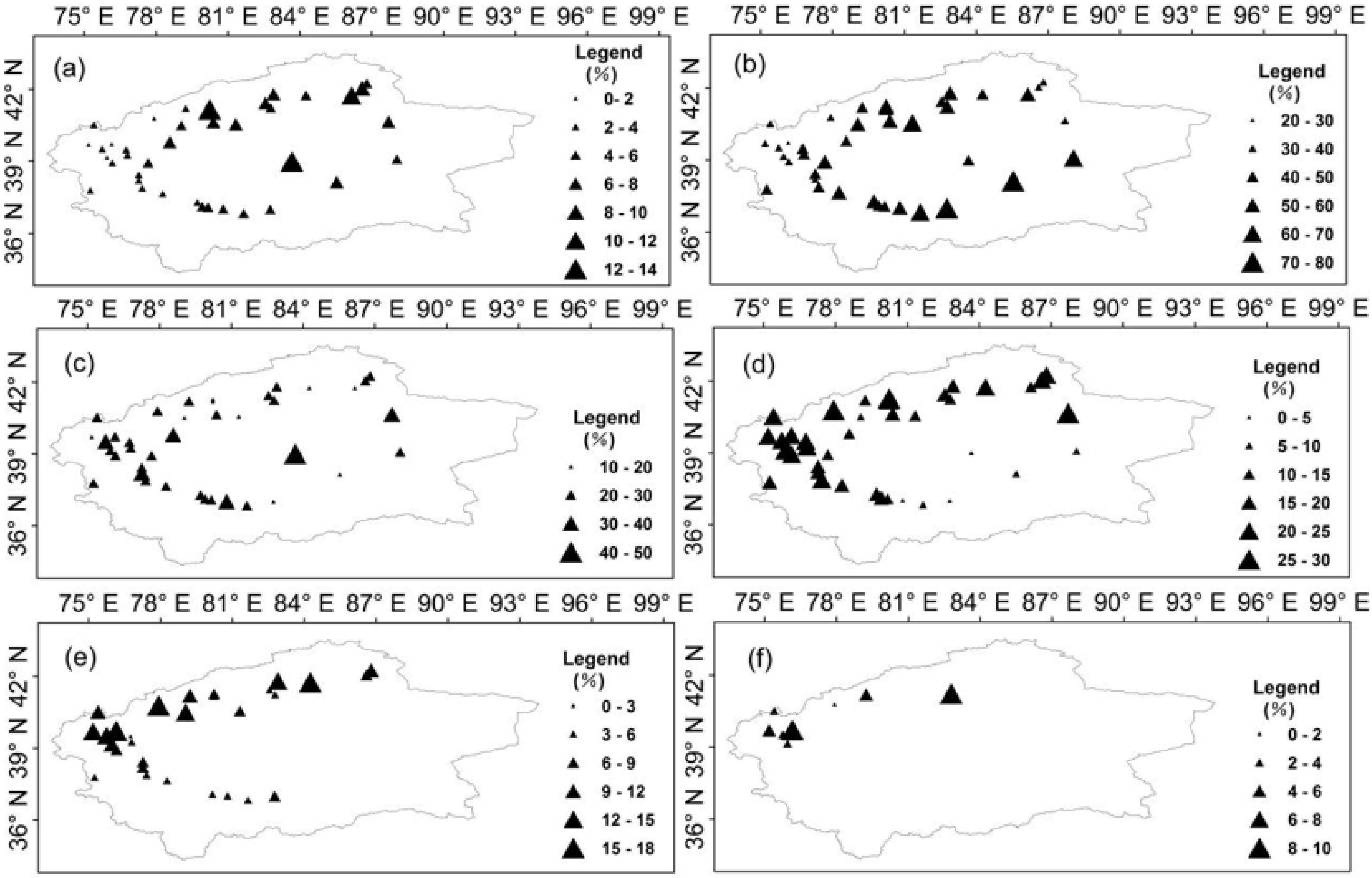

Figure 10

Contribution rate of trace amounts of snow (a), light snow (b), moderate snow(c), heavy snow (d), snowstorm (e), and heavy snowstorm to total snowfall in the TB Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.