Postprint: Variation Characteristics of Precipitation Area in China, 1961-2015

Authors: Zhang Yaning, Zhang Mingjun, Wang Shengjie, Du Mingxia, Ma Rong, Wang Jie, Zhang Mingjun

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Abstract

Based on the 0.5°×0.5° monthly and daily precipitation grid dataset for China, and employing methods including linear trend analysis, Kriging interpolation, and Theil-Sen slope, this study analyzes the variation characteristics of precipitation amount and precipitation area across three natural regions of China from 1961 to 2015. The results indicate: (1) The annual and seasonal mean precipitation in China during 1961–2015 exhibits a spatial distribution pattern decreasing from the southeast coast toward the northwest inland, with over half of the region showing an increasing trend in both annual and seasonal precipitation. (2) In terms of daily variation characteristics, the eastern monsoon region, northwest arid region, and Tibetan Plateau alpine region are all dominated by light rain and moderate rain, with their multi-year average daily precipitation areas being 1,112.75×10^3 km^2 and 52.65×10^3 km^2, 1,380.57×10^3 km^2 and 92.83×10^3 km^2, and 1,253.9×10^3 km^2 and 34.3×10^3 km^2, respectively; heavy rain and torrential rain occupy relatively small areas. The intra-annual variation of daily precipitation area for different grades in all three regions conforms to a quadratic function curve. The interannual variation of daily average precipitation area for light rain in all three regions shows a slight decreasing trend, while heavy rain, rainstorm, and torrential rain in the Tibetan Plateau alpine region and northwest arid region show a slight increasing trend, with torrential rain exhibiting relatively large overall fluctuations. (3) Regarding seasonal variation characteristics, all three regions are dominated by light rain across the four seasons, with relatively small areas occupied by rainstorm and torrential rain. The light rain precipitation area in all three regions shows a decreasing trend in spring and autumn, the rainstorm precipitation area in all three regions shows an increasing trend in spring and summer, and the moderate rain and heavy rain precipitation areas in all three regions show an increasing trend in winter. (4) In the eastern monsoon region in spring and autumn, the northwest arid region on annual and seasonal scales, and the Tibetan Plateau alpine region in

spring, autumn, and winter, the precipitation areas corresponding to different precipitation grades all conform to a negative exponential distribution.

Full Text

Changes of Precipitation Area in China from 1961 to 2015

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Authors: ZHANG Yaning[1], ZHANG Mingjun[1], WANG Shengjie[1], DU Mingxia[1], MA Rong[1], WANG Jie[2]

[1]College of Geography and Environmental Science, Northwest Normal University, Lanzhou 730070, Gansu, China

[2]School of Geographic and Oceanographic Sciences, Nanjing University, Nanjing 210023, Jiangsu, China

Abstract

The non-uniformity of precipitation elements (precipitation amount, precipitation intensity, precipitation frequency, and precipitation area) in time and space leads to frequent occurrence of natural disasters (storms, floods, continuous rain, landslides, mudslides, etc.), causing great losses to people’ s production and life, which has raised great concern. Based on 0.5°×0.5° monthly and daily precipitation grid datasets in China from 1961 to 2015, the characteristics of precipitation and precipitation area in three regions of China were analyzed using linear trend method, Kriging interpolation method, and forest slope method. The annual and seasonal average precipitation presented a decreasing pattern from the southeast coast to the northwest inland, while the annual and seasonal average precipitation in over half of China’ s regions showed an increasing trend. In terms of daily and seasonal variations, light rain and moderate rain were mainly concentrated in the eastern monsoon region and the northwest arid region and the Qinghai-Tibet alpine region of China, but the area occupied by rainstorm and heavy rainstorm was small. The annual variation of daily precipitation area at different levels in the three regions followed a quadratic function curve, and the interannual variation of the average precipitation area in the three regions showed a slight decrease. The heavy rain, rainstorm, and downpour displayed a slightly increasing trend in the Qinghai-Tibet alpine region and the arid areas of northwest China. From the seasonal change characteristics perspective, light rain dominated in all seasons in the three regions. The areas with rainstorm or downpour accounted for a smaller proportion. The precipitation areas of light rain in the three regions in spring and autumn showed a decreasing trend, while rainstorm in spring and summer showed an increasing trend, and moderate rain and heavy rain in winter showed an increasing trend. The variation characteristics of precipitation area in China provide a good basis for formulating climate change strategies. It is also of great significance for the comprehensive management of water resources and flood control and disaster mitigation in the basin.

Keywords: China; precipitation; precipitation area; changing characteristics

1 Data and Methods

1.1 Data Sources and Processing

This study utilized 0.5°×0.5° monthly and daily precipitation grid datasets covering China from 1961 to 2015. The datasets were generated through quality control and interpolation of observations from 2,472 meteorological stations across China, using the Kriging interpolation method. The data accuracy was validated against observations from 753 meteorological stations during 1961-2000 and 69 stations during 2001-2008, showing good agreement.

The precipitation data were categorized into five levels based on daily precipitation amount: light rain (0.1-9.9 mm), moderate rain (10.0-24.9 mm), heavy rain (25.0-49.9 mm), rainstorm (50.0-99.9 mm), and heavy rainstorm (100 mm). The analysis focused on three primary regions: the eastern monsoon region, the northwest arid region, and the Qinghai-Tibet alpine region.

1.2 Analytical Methods

The linear trend method was employed to analyze temporal variations in precipitation and precipitation area. The Kriging interpolation method was used for spatial analysis, implemented through ArcGIS software. The forest slope method was applied to calculate trend rates, with significance testing performed using the Mann-Kendall test. Spatial distributions of annual and seasonal average precipitation were mapped at 0.5°×0.5° resolution.

The precipitation area for each level was calculated as the total area of grid cells where daily precipitation fell within specific ranges. Interannual variations were analyzed using linear regression, with trend rates expressed in units of 10^3 km^2 per decade.

2 Results

2.1 Spatial Distribution of Precipitation

The spatial distribution of annual and seasonal average precipitation in China from 1961 to 2015 showed a clear decreasing gradient from the southeast coast to the northwest interior [Figure 1: see original paper]. Over half of China' s land area exhibited increasing precipitation trends, particularly in the northwest arid region and the Qinghai-Tibet Plateau. The eastern monsoon region showed mixed patterns, with decreasing trends in some areas and increasing trends in others.

presents the linear variation trends of annual and seasonal average precipitation across China. The annual precipitation trend rate was -0.13 mm/(10a) ($P>0.05$) for the eastern monsoon region, 0.22 mm/(10a) ($P<0.01$) for the northwest arid region, and 0.15 mm/(10a) ($P<0.05$) for the Qinghai-Tibet region. Seasonal variations were significant, with winter precipitation showing the strongest increasing trend in northwest China at 0.27 mm/(10a) ($P<0.05$).

2.2 Precipitation Area Variations

2.2.1 Annual Variation Characteristics The annual variation of daily precipitation area at different levels followed distinct patterns. Light rain and moderate rain areas dominated, accounting for 57.5% and 69.3% of total precipitation area respectively, while heavy rain and rainstorm areas comprised smaller proportions .

The interannual variation of precipitation area showed that light rain area decreased significantly in the eastern monsoon region at a rate of -15.37×10^3 $km^2/(10a)$ ($P<0.01$). In contrast, moderate rain area increased in the northwest arid region by 13.4×10^3 $km^2/(10a)$ ($P<0.01$), and heavy rain area increased in the Qinghai-Tibet region by 0.6×10^3 $km^2/(10a)$.

Heavy rainstorm areas showed slight decreasing trends in most regions, except for the Qinghai-Tibet Plateau where a marginal increase was observed. The total area covered by precipitation events of all levels remained relatively stable, with cyclic fluctuations around the long-term mean.

2.2.2 Seasonal Variation Characteristics Seasonal analysis revealed that light rain dominated in all seasons across all three regions . In spring and autumn, light rain areas showed decreasing trends in the eastern monsoon region (-9.5×10^3 $km^2/(10a)$, $P<0.05$) and northwest arid region (-7.5×10^3 $km^2/(10a)$, $P<0.01$), but increased slightly in the Qinghai-Tibet region.

Rainstorm areas exhibited increasing trends in spring and summer, particularly in the northwest arid region where the rate reached 21×10^3 $km^2/(10a)$ ($P>0.05$). Moderate and heavy rain areas in winter showed increasing trends across all regions, with the most significant increase in the eastern monsoon region (12×10^3 $km^2/(10a)$).

The seasonal distribution of precipitation area followed a quadratic function relationship with precipitation intensity, with the correlation coefficients varying by region and season [MATH:0024]. The proportion of area receiving 0–100 mm annual precipitation decreased from 41.32% to 33.12% over the study period, while areas receiving 100–200 mm increased from 25.33% to 31.12%.

2.3 Regional Distribution Patterns

The precipitation area distribution exhibited significant regional differences. In the eastern monsoon region, the area with annual precipitation >500 mm accounted for 63.52% of the region' s total area, while in the northwest arid region, 41.32% of the area received <100 mm annually. The Qinghai-Tibet region showed the most complex pattern, with high-elevation areas receiving more precipitation than low-elevation areas at the same latitude.

The relationship between precipitation area and intensity followed a negative exponential distribution [MATH:0025], with the area decreasing exponentially as precipitation intensity increased. This relationship was particularly pronounced in the northwest arid region and the Qinghai-Tibet alpine region.

4 Conclusion

Based on 0.5°×0.5° gridded precipitation data and using linear trend analysis, Kriging interpolation, and forest slope methods, this study analyzed the spatiotemporal characteristics of precipitation and precipitation area in China from 1961 to 2015. The main conclusions are:

(1) The annual and seasonal average precipitation showed a decreasing pattern from southeast to northwest, but more than half of China' s regions exhibited increasing precipitation trends. The trend rates varied significantly by region and season, with the northwest arid region showing the strongest increasing trend. Light and moderate rain dominated the precipitation area, while heavy rain and rainstorm areas remained relatively small.

(2) The interannual variation of precipitation area at different levels followed quadratic function curves. Light rain area showed a significant decreasing trend in the eastern monsoon region, while moderate rain area increased in the northwest arid region. Heavy rain, rainstorm, and downpour areas displayed slightly increasing trends in the Qinghai-Tibet alpine region and northwest arid areas.

(3) Seasonally, light rain dominated all seasons across the three regions. Light rain areas in spring and autumn showed decreasing trends, while rainstorm areas in spring and summer increased. Moderate and heavy rain areas in winter exhibited increasing trends. The precipitation area distribution followed negative exponential patterns in the eastern monsoon region during spring and autumn, and in the northwest arid region and Qinghai-Tibet region across all seasons.

(4) The relationship between precipitation area and intensity provides a scientific basis for climate change adaptation strategies and water resource management. The increasing trends of heavy precipitation events in arid and alpine regions have important implications for flood control and disaster mitigation.

These findings contribute to understanding precipitation pattern changes under global warming and provide valuable information for regional climate policy formulation and water resource planning in China.

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Note: Figure translations are in progress. See original paper for figures.