

Summer Extreme Precipitation in the Region North and South of the Qinling Mountains and Its Relationship with the Western Pacific Subtropical High: Postprint

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Date: 2019-11-14T00:00:00+00:00

Abstract

Based on daily precipitation data from 47 stations in the region to the north and south of the Qinling Mountains from 1960-2016 and concurrent Western Pacific Subtropical High (WPSH) indices including area index, intensity index, western ridge point, and ridge line position, this study statistically analyzed the correlations between summer extreme precipitation indices and WPSH indices in this region. The results show that: Overall, various extreme precipitation indices are positively correlated with the area index and intensity index; negatively correlated with the western ridge point, although some anomalous years and years with negative correlation occur; whereas the relationship between extreme precipitation indices and ridge line position exhibits alternating positive and negative correlations. Interdecadal analysis and Mann-Kendall test indicate that both WPSH indices and extreme precipitation indices underwent an abrupt shift toward enhancement and increase in the 1980s. After dividing the region to the north and south of the Qinling Mountains into four subregions, both temporally and spatially, when the area index and intensity index are relatively large, the ridge line position is displaced southward, and the western ridge point is displaced westward, areas north of the Qinling Mountains, south of the Qinling Mountains, and the central Han River basin tend toward drought, while the eastern and western parts of the Han River basin and the Ba-Wu valley experience excessive extreme precipitation; conversely, the opposite pattern occurs. Such a pattern of extreme precipitation should represent the climatic response of mountain ranges such as the Qinling to the subtropical high. Years with excessive summer extreme precipitation in the region to the north and south of the Qinling Mountains are associated with a relatively large area index, strong intensity index, southward ridge line position, and westward western ridge point; conversely, the opposite is true. The westward extension of

the subtropical high may be one of the important causes for increased extreme precipitation in the region to the north and south of the Qinling Mountains.

Full Text

Preamble

DOI: 10.13866/j.azr.2019.06.07

Received: 2019-03-29; **Revised:** 2019-06-13

Funding: National Natural Science Foundation of China (41771110); Shaanxi Provincial Natural Science Foundation (2017JM4026)

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1. Introduction

Extreme precipitation events exhibit significant spatial and temporal variability, and their relationship with the western Pacific subtropical high (WPSH) has been extensively studied. Previous research indicates that the WPSH' s area, intensity, ridge line position, and west ridge point substantially influence precipitation patterns in China. The WPSH indices (area, intensity, west ridge point, and ridge line) serve as key indicators for diagnosing summer precipitation anomalies.

This study analyzes the relationship between summer extreme precipitation north and south of the Qinling Mountains and WPSH indices using daily precipitation data from 47 meteorological stations (1960-2016) and WPSH index data from the China Meteorological Administration Climate Data Center (<http://www.cdc.cma.gov.cn>) and the Climate Monitoring Diagnostic Analysis Platform (<http://cmdp.ncc-cma.net/cn/index.htm>). The extreme precipitation indices include: R50 (number of days with daily precipitation ≥ 50 mm), R99P (total precipitation from days exceeding the 99th percentile), SDII (simple daily intensity index), Rx1day (maximum 1-day precipitation), and Rx5day (maximum 5-day precipitation).

2. Data and Methods

Correlation analysis and Mann-Kendall (M-K) tests were employed to examine relationships between extreme precipitation indices and WPSH characteristics. The study area was divided into four regions for spatial analysis. The WPSH indices include: (a) Area index: 10°N-60°N, 110°E-180°E; (b) Intensity index; (c) West ridge point; and (d) Ridge line: 90°E-180°E. The M-K test identifies abrupt changes in both WPSH indices and extreme precipitation indices.

3. Results

3.1 Spatial Correlation Patterns

The R50 index shows significant positive correlations with WPSH area and intensity indices, but negative correlations with the west ridge point index. Specifically, R50 correlates with WPSH area at $r = 0.51$ ($P < 0.001$) and with intensity at $r = 0.15$ ($P < 0.05$). For the ridge line index, both positive and negative correlations appear in different years, suggesting alternating influence patterns.

During 1960–2016, R50 exhibited a mean value of 1.51 days, with a trend of 0.15 days per decade. The SDII averaged $14.97 \text{ mm} \cdot \text{d}^{-1}$, Rx1day averaged 73.05 mm, and Rx5day averaged 115.78 mm, all showing slight increasing trends. R99P averaged 57.44 mm with a trend of $0.22 \text{ mm} \cdot \text{a}^{-1}$.

Spatially, extreme precipitation indices correlate positively with WPSH area and intensity across most regions, but negatively with the west ridge point. The ridge line index shows region-dependent correlations: positive in some areas and negative in others, particularly in the Han River Basin and Ba Valley.

3.2 Temporal Variations by Decade

1960s: WPSH area and intensity indices were low, while ridge line and west ridge point indices were high. Extreme precipitation indices showed decreasing trends, with drought conditions prevalent in the Han River Basin.

1970s: WPSH area and intensity remained low, but the ridge line shifted southward. Extreme precipitation indices continued decreasing, particularly R99P, R50, and SDII, indicating persistent drought conditions north and south of the Qinling Mountains.

1980s: A significant mutation occurred. WPSH area and intensity indices increased, while ridge line and west ridge point indices decreased. Extreme precipitation indices (R99P, R50, Rx1day, Rx5day) increased substantially, particularly in the eastern and western Han River Basin and Ba Valley.

1990s: WPSH area and intensity indices decreased slightly, while ridge line and west ridge point indices increased. Extreme precipitation indices showed mixed patterns: R50 and SDII decreased, while R99P and Rx5day increased.

2000s: WPSH area and intensity indices increased again, with ridge line shifting southward and west ridge point moving westward. Extreme precipitation indices increased, particularly R50, SDII, and Rx5day.

2010s (2010–2016): WPSH area and intensity indices remained high, with the ridge line in a southern position. Extreme precipitation indices showed significant increases, especially R99P, SDII, and Rx1day.

3.3 Abrupt Change Analysis

M-K test results reveal a significant abrupt change in the 1980s for both WPSH indices and extreme precipitation indices. The WPSH area index increased after 1980, with a mutation point around 1985. The intensity index also increased significantly after 1980. Correspondingly, extreme precipitation indices (R50, R99P, SDII, Rx1day, Rx5day) all show significant upward trends after the 1980s, particularly in the Han River Basin and southern regions.

[Figure 2: see original paper] Distribution of summer extreme precipitation in abnormal years with western Pacific subtropical high

[Figure 3: see original paper] Distribution of extreme precipitation in July and August in abnormal years when the ridge line was located to the north

[Figure 4: see original paper] Relationship between R50 and west ridge point and ridge line indices of western Pacific subtropical high

[Figure 5: see original paper] Relationship between R99P and ridge line indices

[Figure 6: see original paper] Relationship between Rx1day and west ridge point indices

The anomalies of western Pacific subtropical high indices and summer extreme precipitation indices

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Abstract: The relationship between summer extreme precipitation in the north and south of the Qinling Mountains and the western Pacific subtropical high was analyzed based on daily precipitation data from 47 stations in the north and south of the Qinling Mountains and data of area, intensity, west ridge point, and ridge line indices of the western Pacific subtropical high from 1960 to 2016. The results showed that: (1) On the whole, the extreme precipitation indices were positively correlated with the area and intensity of the western Pacific subtropical high; they were negatively correlated with the west ridge point, but some abnormal years and negatively-correlated years appeared. The positive and negative correlations between the extreme precipitation indices and the ridge line occurred alternatively. Decadal analysis and M-K test revealed that a mutation increase of the western subtropical high indices and the extreme precipitation indices occurred in the 1980s; (2) After the north and south of the Qinling Mountains were divided into four regions, no matter temporally or spatially, drought occurred in the regions to the north and to the south of the Qinling Mountains and the central Han River Basin, but the frequency of extreme precipitation increased in the east and west parts of the Han River Basin and the Ba Valley when the area and intensity indices were larger, the ridge line

index was more southward, and the west ridge point index was more westward. On the contrary, it was opposite. Such extreme precipitation patterns should be the result of response of the Qinling Mountains to the subtropical high; (3) The increase of summer extreme precipitation in the north and south of the Qinling Mountains in some years was related to the higher area index, intensity index, southward ridge line, and westward ridge point. On the contrary, it was opposite. The westward Pacific subtropical high may be one of the important reasons for the increase of extreme precipitation in the north and south of the Qinling Mountains.

Keywords: summer; extreme precipitation; western Pacific subtropical high index; north and south of the Qinling Mountains

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

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