

Correlation Analysis of Precipitation and Sunspot Activity in the Ankang Region over the Past 63 Years: A Postprint

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Abstract

Based on daily precipitation data from Ankang Station of Ankang Meteorological Bureau and annual relative sunspot numbers from 1953 to 2015, the characteristics of precipitation variation and its relationship with relative sunspot numbers in the Ankang region over the past 63 a were analyzed using methods such as Mann-Kendall abrupt change test and Morlet wavelet analysis. The results show that: over the past 63 a, annual precipitation and summer precipitation in the Ankang region have shown an overall increasing trend, with increases of $0.99 \text{ mm} \cdot \text{a}^{-1}$ and $1.65 \text{ mm} \cdot \text{a}^{-1}$, respectively; precipitation in spring, autumn, and winter showed an overall decreasing trend, with decreases of $0.26 \text{ mm} \cdot \text{a}^{-1}$, $0.35 \text{ mm} \cdot \text{a}^{-1}$, and $0.06 \text{ mm} \cdot \text{a}^{-1}$, respectively; precipitation was concentrated in summer and autumn. There was mainly a 0~3 a lag between extreme annual precipitation anomalies and peak/trough values of relative sunspot numbers; annual precipitation in the Ankang region over the past 63 a had significant variation periods of 3 a and 28 a, which differed to some extent from the 9 a variation period of relative sunspot numbers.

Full Text

Correlation Between Sunspot Activity and Precipitation in the Ankang Region in Recent 63 Years

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Abstract

This study employs the Mann-Kendall test and Morlet wavelet analysis to investigate the variation characteristics of precipitation and its relationship with relative sunspot numbers in the Ankang region over the past 63 years, based on daily precipitation data from Ankang Meteorological Station and relative annual sunspot numbers from the Solar Influences Data Analysis Center for the period 1953–2015. The results indicate that both annual and summer precipitation in the Ankang region exhibited significant increasing trends, with rates of $0.99 \text{ mm} \cdot \text{a}^{-1}$ and $1.65 \text{ mm} \cdot \text{a}^{-1}$, respectively. Spring, autumn, and winter precipitation showed slight decreasing trends of $0.26 \text{ mm} \cdot \text{a}^{-1}$, $0.35 \text{ mm} \cdot \text{a}^{-1}$, and $0.06 \text{ mm} \cdot \text{a}^{-1}$, respectively. Precipitation was concentrated mainly in summer and autumn. A 0–3 year time lag was observed between extreme precipitation anomalies and the peak-valley values of relative sunspot numbers. Wavelet analysis revealed significant variation periods of 3 years and 28 years for annual precipitation in the Ankang region, which differ from the 9-year variation period of relative sunspot numbers.

Keywords: precipitation; sunspot; moving average; wavelet analysis; Ankang region

1 Introduction

The Ankang region is located in the southern part of Shaanxi Province, China, between $108^{\circ}01' - 110^{\circ}01' \text{ E}$ and $31^{\circ}42' - 33^{\circ}49' \text{ N}$. The region covers an area of $2.45 \times 10^4 \text{ km}^2$ with a population of 2.66×10^6 . Characterized by complex topography and a monsoon climate, the region experiences significant precipitation variability that profoundly impacts agricultural production and water resource management. Previous studies have demonstrated relationships between precipitation patterns and large-scale climate indices such as the Pacific Decadal Oscillation (PDO), Arctic Oscillation (AO), and El Niño-Southern Oscillation (ENSO) [9–11]. Solar activity, particularly sunspot cycles, has also been identified as a potential driver of regional precipitation variations [4–5]. This study examines the temporal characteristics of precipitation in the Ankang region and explores its potential linkages with solar activity.

2 Data and Methods

2.1 Data Sources

Precipitation data consist of daily observations from Ankang Meteorological Station for the period 1953–2015. Sunspot data were obtained from the Solar Influences Data Analysis Center (SIDC) as relative annual sunspot numbers.

2.2 Methodology

Mann-Kendall Trend Test: The Mann-Kendall test is a non-parametric statistical method used to detect monotonic trends in time series data. For a

time series X_j (where $j = 1, 2, \dots, n$), the test statistic S_k is calculated as:

$$S_k = \sum_{i=1}^k \sum_{j=1}^{i-1} \text{sgn}(X_i - X_j) \quad (k = 2, 3, \dots, n)$$

where sgn is the sign function. The standardized test statistic UF_k is computed as:

$$UF_k = \frac{S_k - E(S_k)}{\sqrt{\text{Var}(S_k)}}$$

where $E(S_k) = k(k+1)/4$ and $\text{Var}(S_k) = k(k-1)(2k+5)/72$. The backward sequence UB_k is calculated using the same method on the reversed time series. The intersection point of UF_k and UB_k curves within the confidence interval indicates a potential mutation point.

Wavelet Analysis: The Morlet wavelet function $\psi(t) \in L^2(\mathbb{R})$ satisfies the admissibility condition $\int_{\mathbb{R}} \psi(t) dt = 0$. The wavelet transform of a function $f(t) \in L^2(\mathbb{R})$ is defined as:

$$W_f(a, b) = |a|^{-1/2} \int_{\mathbb{R}} f(t) \overline{\psi\left(\frac{t-b}{a}\right)} dt$$

where a is the scale parameter and b is the translation parameter. The wavelet variance is given by:

$$\text{Var}(a) = \int_{-\infty}^{\infty} |W_f(a, b)|^2 db$$

3 Results

3.1 Annual Precipitation Characteristics

The 5-year moving average of annual precipitation shows considerable interannual variability [Figure 1: see original paper]. The average annual precipitation is 813.8 mm, with a maximum of 1231.9 mm in 2012 and a minimum of 525.8 mm in 1999. Three distinct wet periods occurred during 1953-1970, 1981-1999, and 2011-2015, while dry periods were observed during 1971-1980 and 2000-2010. The overall trend shows a significant increase of 0.99 mm per year.

3.2 Seasonal Precipitation Characteristics

Seasonal precipitation variations differ markedly [Figure 2: see original paper]. Spring precipitation averages 184 mm with no significant trend. Summer precipitation, averaging 232.4 mm (28.56% of annual total), shows a significant

increasing trend of 1.65 mm per year, with a maximum of 526.1 mm in 2011 and minimum of 61 mm in 2007. Autumn precipitation averages 376 mm (46.20% of annual total) with a slight decreasing trend. Winter precipitation averages 21.4 mm (2.63% of annual total) with minimal variation.

3.3 Mann-Kendall Mutation Test for Annual Precipitation

The Mann-Kendall test reveals significant mutation points around 1970–1990 [Figure 3: see original paper]. The UF statistic exceeds the critical value during the 1970s–1990s, indicating a significant increasing trend. The intersection of UF and UB curves in the 1980s suggests a mutation point. The UF curve remains positive after 2000, though below the critical value, indicating a weakening trend.

3.4 Mann-Kendall Mutation Test for Seasonal Precipitation

Seasonal analysis shows distinct patterns [Figure 4: see original paper]. Spring precipitation exhibits mutation points in the 1980s. Summer precipitation shows significant increasing trends with mutation points around 1977. Autumn precipitation displays decreasing trends with mutations in 1989–1990 and 2010–2015. Winter precipitation shows minimal trends with scattered mutation points.

3.5 Relationship with Sunspot Activity

The relative sunspot number shows a 9-year periodicity [Figure 5: see original paper]. Precipitation anomalies exhibit a 0–3 year lag relative to sunspot extrema. During sunspot peak years (M years), precipitation anomalies are predominantly negative, while during valley years (m years), anomalies are predominantly positive. This suggests an inverse relationship with a temporal lag.

3.6 Wavelet Analysis

Wavelet analysis reveals different periodicities [Figure 6: see original paper]. Annual precipitation shows significant 3-year and 28-year periods, while sunspot numbers exhibit a dominant 9-year period. The 2–5 year precipitation periods may be associated with ENSO activity, consistent with previous studies showing ENSO's influence on regional precipitation [29–32].

4 Discussion

The observed precipitation trends reflect the complex interplay of multiple forcing factors. While solar activity shows a clear 9-year cycle, precipitation exhibits multi-scale variability with dominant periods of 3 and 28 years. The 0–3 year lag between sunspot extrema and precipitation anomalies suggests a delayed response of the regional hydroclimate to solar forcing. The influence of ENSO, with its typical 2–7 year cycle, may modulate the solar signal, resulting in the

observed 3-year precipitation period. The long-term increasing trend in summer precipitation aligns with regional climate change patterns.

5 Conclusion

Over the past 63 years, the Ankang region has experienced: 1. Significant increases in annual ($0.99 \text{ mm} \cdot \text{a}^{-1}$) and summer ($1.65 \text{ mm} \cdot \text{a}^{-1}$) precipitation 2. Slight decreases in spring, autumn, and winter precipitation 3. A 0–3 year lag of precipitation anomalies relative to sunspot extrema 4. Distinct variation periods of 3 and 28 years for precipitation, differing from the 9-year sunspot cycle

These findings highlight the complex relationships between solar activity and regional precipitation, with implications for water resource management and climate adaptation strategies in the Ankang region.

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