

Main Weather Dynamic Factors Influencing Precipitation Variation in the Qaidam Basin Post-print

Authors: Han Jinjun, Wang Jianping, Chen Liang, Ling Zhiyong, Xiang Jiangyun, Wang Jianping

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Abstract

To investigate the relationship between precipitation variation and factors such as sunspots, Arctic Oscillation (AO), and El Niño-Southern Oscillation (ENSO) in the Qaidam Basin over the past 57 years, linear trend analysis, Mann-Kendall test, and wavelet analysis were employed to analyze precipitation data from 8 meteorological stations within the basin. The results indicate that annual precipitation in the basin has increased at a rate of 0.628 mm per year over the past 57 years, with summer precipitation increasing by 0.423 mm per year, accounting for 67% of the total annual increase. Annual precipitation exhibits significant periodicities of 2-3 years and 1 year. Precipitation and sunspot relative numbers display a dominant resonance period of approximately 8-12 years with positive correlation, with precipitation lagging by 1.2-1.8 years. Annual precipitation and AO primarily exhibit resonance periods of 2-3 years and 1-2 years with approximately positive correlation. Annual precipitation and ENSO show a resonance period of approximately 3 years with negative correlation and 5-6 years with positive correlation. These findings demonstrate that precipitation in the basin exhibits different correlations with its atmospheric dynamic factors at different periodic scales.

Full Text

Preamble

The Main Weather Dynamic Factors Affecting Precipitation Change in the Qaidam Basin

HAN Jin-jun^{1,2,3}, WANG Jian-ping^{1,2}, CHEN Liang^{1,2}, LING Zhi-yong^{1,2}, XIANG Jiang-yun^{1,2,3}

¹Key Laboratory of Comprehensive and Highly Efficient Utilization of Salt Lake Resources, Qinghai Institute of Salt Lakes, Chinese Academy of Sciences, Xining 810008, China;

²Qinghai Provincial Key Laboratory of Geology and Environment of Salt Lake, Xining 810008, China;

³University of Chinese Academy of Sciences, Beijing 100049, China

Abstract: To study the trends in precipitation and their relationships with sunspots, the Arctic Oscillation (AO), and the El Niño-Southern Oscillation (ENSO) in the Qaidam Basin over the previous 57 years, linear trend analysis, anomaly analysis, Mann-Kendall test, and wavelet analysis methods were applied to precipitation data from eight meteorological stations located in the basin. The results showed that the mean annual precipitation in the basin increased by 0.628 mm, while summer precipitation increased by 0.423 mm during the 57-year period. Summer precipitation accounted for 67% of the total annual increase, and the mean annual precipitation exhibited significant variation periods of 2-3 years and 1 year. A significant approximately in-phase resonance oscillation of 8-12 years could be observed between annual precipitation and sunspot numbers, with precipitation lagging by 1.2-1.8 years. The mean annual precipitation and AO exhibited approximately in-phase resonance oscillations of 2-3 years and 1-2 years. The mean annual precipitation was inversely related to ENSO during a 3-year resonant period and was almost positively related to ENSO in a 5-6 year resonant period. These results indicated that there were different correlations between precipitation and the dynamic weather factors at different periodic scales.

Keywords: precipitation; sunspot; AO; ENSO; Qaidam Basin

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Corresponding Author: HAN Jin-jun; Email: hjj@isl.ac.cn

2 Data and Methods

2.1 Data Sources

Precipitation data were obtained from eight meteorological stations in the Qaidam Basin. The mean annual precipitation was 83 mm, with a maximum of 141.6 mm recorded in 2010 and a minimum of 41.5 mm in 1965. Analysis of the 57-year dataset revealed that precipitation below 80 mm occurred in 21 years, often associated with ENSO events. The relative sunspot number data, AO index, and Oceanic Niño Index (ONI) were used as primary climate indices. The ONI index showed strong El Niño years in 1977, 1989, 1998, and 2010, with values exceeding 0.5°C above normal, while 2015 marked the strongest

El Niño event in 57 years. La Niña events were identified in 1961, 1968, 1984, 1995, and 2001, with ONI values below -0.5°C . Precipitation anomalies showed periodicities of 0–3 years during 1963, 1965, 1969, 1972, 1982–1983, 1987, 1991–1992, 1997, and 2002, and 5–6 year cycles during 1964–1968, 1980–1987, and 1983–1998.

2.5 Wavelet Analysis Methods

Wavelet analysis was employed to examine multi-scale relationships between precipitation and climate factors. The continuous Morlet wavelet transform was applied to identify dominant periodicities in the precipitation time series. Cross-wavelet transform and wavelet coherence analysis were used to investigate phase relationships and coherence between precipitation and sunspot numbers, AO, and ENSO indices. The 95% confidence level was used to assess statistical significance, with the cone of influence indicating regions affected by edge effects. Phase arrows in the cross-wavelet spectra denoted the relative timing: right-pointing arrows indicated in-phase relationships, left-pointing arrows indicated anti-phase relationships, and vertical arrows showed precipitation leading or lagging the climate factor by 90° .

Fig. 4 shows the temporal sequence of annual precipitation anomaly relative to sunspot numbers, the Arctic Oscillation index, and the El Niño index. Significant 8–12 year periodicities were observed between precipitation and sunspot numbers, with precipitation lagging by 1.2–1.8 years. The precipitation-AO relationship exhibited 2–3 year and 1–2 year periodicities, while precipitation-ENSO showed inverse relationships at 3-year scales and positive relationships at 5–6 year scales.

Fig. 5 displays the continuous Morlet wavelet power spectrum of mean annual precipitation and major weather dynamic factors in the Qaidam Basin. The black bold line represents the 95% confidence level border, and the thin curve indicates the cone of influence. Precipitation showed significant power at 2–3 year and 8–12 year scales, while AO exhibited 2–3 year and 16-year periodicities, and ENSO displayed 3-year and 3–5 year periodicities.

Fig. 6 presents the cross-wavelet transform and wavelet coherence between annual precipitation and relative sunspot numbers. Significant coherence occurred at 8–12 year scales during 1966–1996, with precipitation lagging sunspots. Additional significant periods appeared at 6-year scales (2000–2017) and 3-year scales (1961–1968).

Fig. 7 shows cross-wavelet analysis between precipitation and the Arctic Oscillation index. Significant 2–3 year coherence was detected during 1964–1969 and 2007–2010, with in-phase relationships. A 1-year periodicity was significant during 2009–2014.

Fig. 8 illustrates cross-wavelet transform and wavelet coherence between precipitation and the El Niño index. Significant 3-year inverse relationships occurred

during 1965–1968 and 1983–1998, while 1.5-year periods showed positive correlations during 2010–2013. The 6-year periodicity during 1992–2002 also showed significant coherence.

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