Dry-Wet Conditions and Their Impact Factors in the Qaidam Basin, 1961–2017: Postprint

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Abstract

Based on meteorological data from 8 stations in the Qaidam Basin during 1961–2017, the potential evapotranspiration was calculated using the Penman-Monteith model recommended by the Food and Agriculture Organization (FAO) of the United Nations, and the wetness index was subsequently derived. Employing methods including climate tendency rate, Mann-Kendall test, Morlet wavelet period, and principal component analysis, the characteristics of dry-wet variations and their influencing factors in the Qaidam Basin were investigated. The results indicate that: during 1961–2017, the Qaidam Basin exhibited an overall wetting trend with a climate tendency rate of $0.007 \cdot (10a)^{1}$ (0.001). The interannual variation of the wetness index fluctuated substantially, with a coefficient of variation of 30.73%. The wetness index in spring, summer, autumn, and winter all displayed increasing trends, with tendency rates of $0.003 \cdot (10a)^{1}$, $0.009 \cdot (10a)^{1}$, $0.004 \cdot (10a)^{1}$, and $0.003 \cdot (10a)^{1}$, respectively. Spatial variation differences were pronounced; the wetting trend in the eastern basin exceeded that in the western region, with Delingha and Dulan showing the most significant wetting trends. The wetness index experienced abrupt changes in 1981 and 1986, and exhibited variation periods of 2.8 a and 3.6 a (0.05), which corresponded well with the 2–4 a period of atmospheric circulation. Principal component analysis revealed that precipitation and mean temperature were the primary influencing factors of the wetness index in the Qaidam Basin. Furthermore, the wetness index was closely correlated with the area and intensity of the Northern Hemisphere polar vortex and the Asian polar vortex, with correlation coefficients of -0.46, -0.36, -0.49, and -0.47, respectively, all passing the 99% significance test.

Full Text

Preamble

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1 Introduction

Climate change has significantly altered the frequency and intensity of extreme weather events globally, with droughts and floods becoming increasingly prominent. Previous studies have documented various aspects of these changes: Plummer et al. [7] analyzed extreme climate events in Australia and New Zealand during the 20th century; Costa and Soares [8] examined local spatiotemporal dynamics of aridity indices in desertification-prone regions; Sarlak and Agha [9] investigated spatial and temporal variations of aridity indices in Iraq; Salvati et al. [10] explored long-term land cover changes and climate variations at the country scale; Rayne and Forest [11] found increasing variability in the Palmer Drought Severity Index in the United States since 1895; and numerous studies have focused on drought-wetness variations in China [12-20].

Research on the Qaidam Basin has revealed significant climate trends: temperature has increased at $0.46°C \cdot (10a)^{1}$, precipitation at $6.496\ mm \cdot (10a)^{1}$, while potential evapotranspiration (ET) decreased by $12.955\ mm \cdot (10a)^{1}$ over 57 years, with mean values of 3.662°C, 83.303 mm, and 1234.041 mm respectively [1]. The region experienced a notable shift from warm-dry to warm-wet conditions around 1986 [2]. However, comprehensive analysis of surface humidity index variations and their driving mechanisms remains limited. This study addresses this gap by analyzing spatiotemporal patterns of humidity indices in the Qaidam Basin from 1961-2017.

2.2 Methods

The Penman-Monteith model was applied to calculate ET using meteorological data from eight stations in the Qaidam Basin. Surface humidity indices were derived, and their spatiotemporal variations were analyzed using Inverse Distance Weighted (IDW) interpolation, Mann-Kendall (M-K) trend testing, Morlet wavelet analysis, and principal component analysis.

2.2.1 Trend Analysis Table 1 presents the trend rates for temperature, precipitation, and ET in the Qaidam Basin over the past 57 years. Temperature showed significant increasing trends across all stations, with rates ranging from 0.281°C · (10a) 1 to 0.632°C · (10a) 1 (0.01). Precipitation trends were more variable, with some stations showing increases (e.g., 43.750 mm · (10a) 1 and 22.215 mm · (10a) 1) while others decreased (e.g., -24.865 mm · (10a) 1, -15.832 mm · (10a) 1). ET generally decreased, with significant declines at most stations (e.g., -34.230 mm · (10a) 1, -51.109 mm · (10a) 1).

Table 1
Trend rates of temperature, precipitation, and ET in the Qaidam Basin in recent 57 years

Station	Temperature [°C · (10a) 1]	Precipitation [mm · (10a) 1]	ET [mm · (10a) 1]
Station 1	0.827**	-24.865**	16.094**
Station 2	0.421**	-15.832**	-4.766
Station 3	0.441**	43.750**	2.175
Station 4	0.632**	5.883	3.670*
Station 5	0.290**	22.215**	-22.412**
Station 6	0.414**	-34.230**	-
Station 7	0.418**	-51.109**	-
Station 8	0.281**	-	-

Note: , ** indicate significance at = 0.05 and = 0.01 levels, respectively.*

Figure 2 shows the annual changes in temperature, precipitation, and ET from 1961-2017, revealing distinct interannual variability and phase differences between these variables.

[Figure 2: see original paper]

Figure 3 illustrates the annual and seasonal variations of the humidity index, which increased at 0.007 · (10a) 1 overall. Seasonally, spring, summer, autumn, and winter showed increasing trends of 0.003 · (10a) 1, 0.009 · (10a) 1, 0.004 · (10a) 1, and 0.003 · (10a) 1 respectively. The interannual variation coefficient was 30.73%, indicating substantial year-to-year variability.

[Figure 3: see original paper]

Spatial analysis revealed significant differences across the basin, with more pronounced humidity index increases in the eastern than western regions. Mutation points occurred in 1981 and 1986. Wavelet analysis identified significant periodicities of 2.8 years and 3.6 years (0.05), consistent with the 2-4 year periodicity of general atmospheric circulation.

Principal component analysis showed that precipitation and average temperature were the primary factors affecting humidity index variation. Correlation analysis with atmospheric circulation indices demonstrated significant negative correlations: the humidity index correlated with PVA at -0.46, PVI at -0.36, APVI at -0.49, and APVII at -0.47 (0.01).

Figure 7 presents the Pareto distribution of humidity index variance contribution and its cumulative distribution, along with double scatter plots of principal component loads and scores.

[Figure 7: see original paper]

Figure 8 shows the correlation analysis between the humidity index and atmospheric circulation indices, confirming the statistical relationships.

[Figure 8: see original paper]

5 Conclusion

The study reveals a wetting trend in the Qaidam Basin from 1961-2017, with significant spatiotemporal heterogeneity. The 2.8-3.6 year periodicities align with atmospheric circulation patterns, and precipitation and temperature emerge as dominant drivers. The strong negative correlations with atmospheric circulation indices (PVA, PVI, APVI, APVII) underscore the influence of large-scale climate dynamics on regional humidity variations.

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Abstract: The Penman-Monteith model was applied to estimate evapotranspiration (ET) values in the Qaidam Basin during 1961-2017 based on meteorological data from eight stations. Surface humidity index values were derived, and climate tendency rate, IDW interpolation, M-K test, Morlet wavelet, and principal component analysis were used to analyze spatiotemporal variation of humidity index and its affecting factors. Results showed that the humidity index in recent 57 years increased at 0.007 · (10a)^{1}, revealing a wetting regional climate in the Qaidam Basin. Interannual variation of the humidity index was significant, with a variable coefficient of 30.73%. Seasonally, spring, summer, autumn, and winter humidity indices all increased, with tendency rates of 0.003 ·

(10a) ^{1}, 0.009 · (10a) ^{1}, 0.004 · (10a) ^{1}, and 0.003 · (10a) ^{1} respectively. Spatially, variation differences were very significant, with more pronounced humidity index increases in the eastern than western basin. Mutation of humidity index occurred in 1981 and 1986, with 2.8-year and 3.6-year periods (0.05), relatively identical to the 2-4-year periodicity of general atmospheric circulation. Principal component analysis showed precipitation and average temperature were the main factors affecting humidity index variation. Additionally, correlation coefficients between humidity index and PVA, PVI, APVI, and APVII were -0.46, -0.36, -0.49, and -0.47 (0.01) respectively.

Keywords: drought/wet event; potential evapotranspiration; climate change; humidity index; Penman-Monteith model; Qaidam Basin