Temperature Variations Under Different Climate Normals in the Eastern Hexi Corridor and Their Impacts on Climate Assessment: Postprint

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Abstract

Abstract: The eastern Hexi Corridor is a sensitive region to climate change, and the shift of climate normals has a significant impact on climate assessment. Using monthly temperature data from 1961 to 2022 from 5 national meteorological stations in the eastern Hexi Corridor, this study comparatively analyzes the differences in temperature among four climate normals (1961-1990, 1971-2000, 1981-2010, and 1991-2020) and their influence on climate operational assessment. The results indicate that: annual mean temperatures for the entire region and individual localities across the four climate normals all show an increasing trend, with the warming trends from P2 (1971-2000 climate normal) to P4 (1991-2020 climate normal) being extremely significant. Based on temperature differences among the four climate normals, annual, seasonal, and monthly temperatures for the entire region and individual localities exhibit basically consistent warming. Except for P3 (1981-2010 climate normal) and P4, other climate normals display the largest increase in winter and the smallest increase in summer, with considerable differences in warming among months and notable spatial differences in temperature increase for the same season and month. After the replacement of climate normal means, the characteristic of significantly large temperature anomalies in the eastern Hexi Corridor is weakened, with the assessment category adjusting from positive anomalies toward negative anomalies. From P1 (1961-1990 climate normal) to P4, the annual mean temperature assessment category shifted to one level lower in 56%-87% of cases, cold winter years increased by 17-28 years, and warm winter years decreased by 15-23 years. This study provides a reference basis for understanding temperature variation patterns in the eastern Hexi Corridor and for climate operations, decision-making services, and meteorological scientific research.

Full Text

Temperature Changes in Different Climate States and Their Influence on Climate Evaluation in the Eastern Hexi Corridor

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Abstract: The eastern Hexi Corridor is a region sensitive to climate change, where shifts in climate states significantly affect climate evaluation. Using monthly temperature data from five national meteorological stations in the eastern Hexi Corridor from 1961 to 2022, this study compares temperature differences across four climate states (1961–1990, 1971–2000, 1981–2010, and 1991–2020) and analyzes their impact on operational climate assessment. The results show that annual mean temperatures across the entire region and individual stations exhibited warming trends in all four climate states, with particularly pronounced and statistically significant warming in the P2 (1971–2000) and P4 (1991–2020) states. Analysis of temperature differences between climate states reveals consistent warming across annual, seasonal, and monthly scales for the region as a whole and for individual stations. Except for the transition from P3 (1981–2010) to P4, other state transitions showed maximum warming in winter and minimum warming in summer. Monthly warming varied considerably, with significant spatial differences in temperature increase observed within the same season and month. Following the update of climate state averages, the pronounced positive temperature anomalies in the eastern Hexi Corridor were substantially weakened, with evaluation grades shifting from positive to negative anomalies. Annual mean temperature ratings transitioned to a lower grade in 56%–87% of years. Cold winter years increased by 17–28 years, while warm winter years decreased by 15–23 years from P1 (1961–1990) to P4. This study provides a reference for understanding temperature variation patterns and for improving climate services, decision-making support, and meteorological research in the eastern Hexi Corridor.

Keywords: climate warming; temperature climate state; change; climate assessment; eastern Hexi Corridor

1. Study Area Overview

The eastern Hexi Corridor is located in central Gansu Province, at the intersection of the Qinghai-Tibet Plateau, Loess Plateau, and Mongolian Plateau. Geographically situated between 101°41 –104°16 E and 36°29 –39°27 N, the terrain slopes from high in the south to low in the north, tilting from southwest to northeast. Elevation decreases from 4850 m to 1300–2000 m. The region comprises four distinct areas: the Minqin desert region in the north, the Liangzhou oasis plain in the center, the Yongchang and Gulang shallow mountainous areas in the north and south, and the Tianzhu Qilian Mountain alpine region. The region exhibits large north-south temperature differences, low precipitation, abundant sunshine, and strong evaporation. The annual mean temperature ranges from 0.7–9.4°C, annual precipitation from 120.8–431.1 mm, annual pan evaporation from 1567.9–2631.3 mm, and annual sunshine duration from 2650.8–3189.3 h (all based on recent climate values). Evaporation is 3.6–21.8 times precipitation. The region belongs to the continental temperate arid and semi-arid climate zone [Figure 1: see original paper].

2. Data and Methods

2.1 Data

Monthly mean temperature observation data from 1961–2022 for five national meteorological stations (Yongchang, Liangzhou, Minqin, Gulang, and Tianzhu at Wushaoling) in the eastern Hexi Corridor were obtained from the Gansu Provincial Meteorological Information Center. The data have undergone strict quality control, with long time series, good completeness, continuity, and high reliability. Regional annual, seasonal, and monthly temperatures represent the average values of all counties and districts. Seasons are defined as spring (March–May), summer (June–August), autumn (September–November), and winter (December–February). For convenience, the four climate states are denoted as P1 (1961–1990), P2 (1971–2000), P3 (1981–2010), and P4 (1991–2020), with their respective climate baseline mean temperatures represented as T_1, T_2, T_3, and T_4.

2.2 Methods

2.2.1 Linear Trend Method The linear trend method was employed to analyze temperature trends across climate states. The linear trend equation is $x = at + b$, where x represents annual mean temperature, t denotes time, a is the climate tendency rate (rate of change of x with t), b is the constant term, and n is the number of study years. The significance of trends was tested using the correlation coefficient between x and t, known as the climate trend coefficient. Based on Monte Carlo simulation methods, when the correlation coefficient exceeds critical values of 0.05, 0.01, and 0.001, the trends are considered moderately significant, significant, and highly significant, respectively.

2.2.2 Climate Evaluation Standards To analyze the impact of changing climate averages on temperature evaluation, we referenced the “Interim Measures for Quality Assessment of Short-term Climate Prediction” issued by the China Meteorological Administration, adapting temperature anomaly grade criteria to local conditions in the eastern Hexi Corridor (Table 1). The evaluation uses temperature anomalies (difference between observed value and climate mean). Grades were assessed for each climate state to examine how changing baseline averages affect annual mean temperature evaluation.

2.2.3 Cold/Warm Winter Criteria According to national standards "Cold Winter Grade" (GB/T 33675—2017) and "Warm Winter Grade" (GB/T 21983—2020), cold and warm winters are identified using 0.43 times the standard deviation of the climate state mean temperature as the threshold. A winter is classified as cold if its temperature anomaly is $\leq$ -0.43σ, and warm if the anomaly is $\geq$ +0.43σ.

3. Results

3.1 Annual Mean Temperature Changes

Table 2 presents the mean values, climate tendency rates, trend coefficients, and differences in tendency rates for the four climate states in the eastern Hexi Corridor. Annual mean temperatures across all states show warming trends (Figure 2). The climate tendency rates for P1–P4 are 0.159–0.378°C/10yr, 0.282–0.865°C/10yr, 0.013–0.226°C/10yr, and 0.385°C/10yr, respectively. Under the $\alpha = 0.05$ significance level, only Minqin's P1 trend passed the test, showing significant warming, while other regional and local trends were not significant. Under $\alpha = 0.01$, all regional and local trends for P2–P4 passed significance testing, indicating highly significant warming. Comparisons between states show that differences in climate tendency rates are mostly positive, demonstrating that the warming trend in the eastern Hexi Corridor is intensifying, particularly for P1–P2 and P3–P4.

3.2 Differences in Annual Mean Temperature

Analysis reveals clear warming across all climate states. Compared with P1, temperature increases for successive states are: P1–P2: 0.2–0.4°C, P2–P3: 0.4–0.6°C, and P3–P4: 0.4–0.7°C. The cumulative increase from P1–P4 reaches 1.0–1.5°C, indicating pronounced progressive warming. Consequently, as climate averages rise, temperature anomalies decrease, altering the classification of years from warm/normal/cold based on the original baseline. Spatial analysis shows that Minqin exhibits the largest warming, followed by Gulang and Liangzhou, with Tianzhu showing the smallest increase.

3.3 Seasonal Temperature Differences

Seasonal warming varies significantly across climate states (Figure 3; Table 3). For P1–P2, winter shows the greatest warming (1.0–1.8°C), followed by spring (0.9–1.6°C), autumn (0.4–0.9°C), and summer (0.1–0.3°C). For P2–P3, warming is less pronounced: winter (0.2–0.3°C), spring and autumn (0.2°C), and summer (0.2–0.3°C). For P3–P4, the pattern reverses, with spring showing maximum warming (0.4–0.7°C), followed by summer and autumn (0.3–0.6°C), and winter (0.2–0.5°C). Overall, winter and spring demonstrate the most significant warming, though spatial differences within seasons are evident.

3.4 Monthly Temperature Differences

Monthly temperature changes across climate states reveal considerable variation (Table 4). For P1–P2, most months show warming except January (some stations cooled) and February (small increases). For P2–P3, all months warm, with March, April, September, and October showing larger increases. For P3–P4, warming continues though some stations (Yongchang, Tianzhu) cooled in January, with March, April, October, and November showing substantial increases. The cumulative P1–P4 changes show winter months with the largest warming (up to 2.6°C), followed by spring and autumn (1.0–1.8°C and 0.8–1.4°C), and summer (0.9–1.6°C). Monthly warming exhibits significant spatial heterogeneity.

4. Impact on Climate Evaluation

4.1 Impact on Annual Mean Temperature Grade Evaluation

Climate average updates substantially affect climate prediction and assessment, particularly when differences between averages are large. Using the grade criteria in Table 1, we evaluated annual mean temperatures for each climate state. Based on P1, most years were classified as "normal slightly high," with "obviously high" second, and no "abnormally low" years. Using P2, "normal slightly low" years became most frequent, with "normal slightly high" second. Using P3, "normal slightly low" dominated, followed by "normal slightly high." Using P4, "obviously low" years were most common. The shift from positive to negative anomalies is evident: 6–17 years shifted lower for P1–P2, 4–12 years for P2–P3, 3–7 years for P3–P4, and 23–32 years cumulatively for P1–P4. This represents 23%–61%, 20%–52%, 39%–73%, and 56%–87% of total years, respectively (Table 5; Figure 4). The increasing climate average baseline systematically adjusts ratings from positive to negative anomalies, weakening the characteristic of large positive temperature anomalies.

4.2 Impact on Cold/Warm Winter Events

Climate average changes significantly affect cold/warm winter events. Re-evaluation using national standards shows cold winters increasing and warm winters decreasing across climate state transitions (Table 6). Cold winter years increased by 5–16 years for P1–P2, 8–12 years for P2–P3, 3–7 years for P3–P4, and 17–28 years cumulatively for P1–P4. Warm winter years decreased by 6–12 years for P1–P2, 7–11 years for P2–P3, 1–5 years for P3–P4, and 15–23 years cumulatively for P1–P4. This trend is consistent across the region and individual stations.

5. Discussion

This study examined temperature trends, mean differences, and impacts on climate evaluation across four climate states (1961–1990, 1971–2000, 1981–2010, 1991–2020) in the eastern Hexi Corridor. The warming rate of 0.40°C/10yr exceeds both the national average (0.24°C/10yr) and global average (0.20°C/10yr), confirming this region as a rapid warming area. While global surface temperature warming slowed after 2013–2014, the eastern Hexi Corridor shows accelerating warming, highlighting the local characteristics of climate change requiring further investigation. This analysis focused on temperature and cold/warm winter events; future work should evaluate impacts on meteorological disasters and other climate elements that also use temperature climate states.

6. Conclusions

1. Annual mean temperatures across the eastern Hexi Corridor show significant warming trends in all four climate states, with highly significant increases in P2–P4. Climate tendency rates increase successively, indicating intensifying regional warming.

2. Successive climate states exhibit consistent warming across annual, seasonal, and monthly scales. Cumulative P1–P4 warming reaches 1.0–1.5°C annually, 0.9–1.8°C seasonally (winter maximum, summer minimum), and 0.8–2.6°C monthly, with substantial spatial variation.

3. Climate average updates shift temperature grades from positive to negative anomalies, weakening large positive anomalies. For P1–P4, 56%–87% of annual mean temperature ratings shifted one grade lower.

4. Climate state transitions increased cold winter years by 17–28 years and decreased warm winter years by 15–23 years from P1 to P4.

These findings enhance understanding of temperature variation patterns and improve climate services and decision-making support in the eastern Hexi Corridor.

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