Variation Characteristics of Mean and Extreme Temperatures in Ningxia, 1962–2015: Postprint

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Abstract

Climatic environment represents an uncontrollable factor in ecological health and sustainable social development, while temperature constitutes a critical condition for maintaining climate system stability and providing habitable conditions for human populations. To characterize the variation features of mean temperature and extreme temperature events in the Ningxia region, linear trend estimation, wavelet analysis, correlation analysis, and other methods were employed to analyze mean temperature and extreme temperature events in Ningxia from 1962 to 2015. The results indicate that since 1962, the entire Ningxia region, its northern part, central arid zone, and southern mountainous area have warmed at rates of 0.38 °C · (10a)^{1}, 0.42 °C · (10a)^{1}, 0.36 °C · (10a)^{1}, and 0.38 °C · (10a)^{1}, respectively. Temperature variations mainly exhibit periodicities of 20–32 a, 8–19 a, and 2–7 a, with dominant periods of 13 a and 32 a possessing secondary periods of 8 a and 20 a, respectively. The frequency and duration of extreme low-temperature events are lower than those of high-temperature events; the increase in low temperatures across the four seasons is greater than that of high temperatures, and the variation is more pronounced in winter. The increase in mean temperature and extreme high temperature will intensify drought conditions in the Ningxia region and exacerbate climate imbalance across the entire region; the reduction in extreme low-temperature indices will increase the incidence of pests and diseases in croplands, forests, and other ecosystems, leading to further ecosystem degradation, and appropriate mitigation measures should be implemented.

Full Text

3.1.1 Temperature Trends in Ningxia from 1962 to 2015

The linear trend analysis reveals that the average temperature in Ningxia increased significantly during the period 1962–2015. The warming rates were

0.38°C · (10a) ^{1} for the entire region, 0.42°C · (10a) ^{1} for the northern and central arid zones, and 0.36°C · (10a) ^{1} and 0.38°C · (10a) ^{1} for the southern mountainous regions, respectively. These trends passed significance tests at the 0.05 level, indicating robust warming across all sub-regions.

[Figure 2: see original paper]

3.1.2 Wavelet Analysis of Temperature Variability

Wavelet analysis of the average annual temperature series from 1962 to 2015 identifies three primary periodic components: 20–32 years, 8–19 years, and 2–7 years. The 20–32 year period exhibited the strongest oscillation amplitude, with temperature fluctuations showing alternating warm and cold phases at approximately 10-year intervals. Within this main period, two sub-periods of 13 years and 32 years were detected, containing secondary cycles of 8 years and 20 years, respectively. The 8–19 year period displayed four distinct phases: 1970–1982 (cold), 1982–1987 (warm), 1987–1992 (cold), and 1992–1997 (warm), with a transition back to cold conditions after 1997. The 2–7 year period represented high-frequency oscillations, with abrupt temperature changes occurring around 1975.

Analysis of extreme temperature indices shows contrasting trends. The frost day index (FD0) and ice day index (ID0) decreased at rates of -4.44 d · (10a) ^{1} and -3.03 d · (10a) ^{1}, respectively, reducing by 15 days over the 54-year period. Conversely, summer days (SU25) and tropical nights (TR20) increased at 3.33 d · (10a) ^{1} and 1.45 d · (10a) ^{1}, respectively. The FD0 index showed higher values during the 1960s–1970s, lower values in the 1980s, and a slight increase after the 1990s. The ID0 index peaked in the 1980s, with a decreasing trend in the 21st century, though some high-value years occurred in the 2010s. SU25 exhibited a stepwise increase, while TR20 showed a gradual upward trend from 1962 to 2015 with main periods of 32 years, 13 years, and 6 years.

[Figure 3: see original paper]

Further analysis of extreme temperature indices reveals that warm daytimes (TX10) and warm nights (TN10) decreased at -4.29 d · (10a) ^{1} and -2.11 d · (10a) ^{1}, respectively, shortening by 23 days and 11 days. Cold daytimes (TX90) and cold nights (TN90) increased at 4.51 d · (10a) ^{1} and 3.13 d · (10a) ^{1}, extending by 24 days and 17 days. The diurnal temperature range (DTR) showed a decreasing trend, particularly pronounced between the 1980s and 2010–2015.

[Figure 4: see original paper]

The growing season length (GSL) and warm spell duration index (WSDI) increased significantly at 4.44 d · (10a) ^{1} and 0.73 d · (10a) ^{1}, respectively, lengthening by 24 days and 4 days. The cold spell duration index (CSDI) decreased at -1.11 d · (10a) ^{1}, shortening by 6 days. The GSL showed a stepwise pattern with abrupt changes, while WSDI increased most notably during 2010–2015.

[Figure 5: see original paper]

Seasonal analysis indicates that extreme temperature events varied significantly across seasons, with winter showing the most pronounced fluctuations.

3.2.3 Correlation and Periodic Characteristics

Correlation analysis reveals strong relationships between temperature indices. Maximum temperature (TMAX) correlates positively with TN90 and TX90, while minimum temperature (TMIN) shows stronger correlations with DTR and extreme indices. TMAX trends range from $0.2°C \cdot (10a)^{1}$ to $0.49°C \cdot (10a)^{1}$ across seasons, with the most significant warming in autumn ($0.49°C \cdot (10a)^{1}$). TMIN trends vary from $0.41°C \cdot (10a)^{1}$ to $0.72°C \cdot (10a)^{1}$, with the strongest increase in winter ($0.72°C \cdot (10a)^{1}$). The seasonal variability of TMIN exceeds that of TMAX, particularly in winter.

The 21st century shows intensified warming with increased climate extremes. The Arctic Oscillation (AO) and other circulation patterns significantly influence temperature variability in Ningxia, with anthropogenic warming superimposed on natural climate variability.

[Figure 6: see original paper]

References

〔1〕Meehl G A, Tebaldi C. More intense, more frequent, and longer lasting heat waves in the 21st century〔J〕. Science, 2004, 305: 994-997.

〔2〕IPCC. Climate change 2013: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation〔M〕. Cambridge: Cambridge University Press, 2013.

〔3〕Chen Jianyu, Zhao Jingbo. Trends of extreme weather events in Inner Mongolia during the period of 1960-2014〔J〕. Arid Zone Research, 2017, 34(5): 997-1009.

〔4〕Houghton J T, Ding Y, Griggs D J, et al. Climate Change 2001: The Scientific Basic〔M〕. Cambridge: Cambridge University Press, 2001: 156-159.

〔5〕Brown S J, Caesar J, Ferro C A T. Global changes in extreme daily temperatures since 1950〔J〕. Journal of Geophysical Research-Atmospheres, 2008, 113(D5): 1-11.

〔6〕Ren Guoyu, Feng Guolin, Yan Zhongwei. Progresses in observation studies of climate extremes and changes in mainland China〔J〕. Climatic and Environmental Research, 2010, 15(4): 337-353.

〔7〕Liu Lin, Xu Zongxue. Spatiotemporal distribution of extreme climate indices in the five Southwestern Provinces of China〔J〕. Resources and Environment in the Yangtze Basin, 2014, 23(2): 294-301.

〔8〕(Content appears corrupted; reference incomplete)

〔9〕Wu Can, Zhao Jingbo, Wang Gehui. Characteristic analysis of the climatic revolution in the Yellow River extreme temperature index〔J〕. Chinese Journal of Agrometeorology, 2015, 36(5): 525-535.

〔10〕(Content appears corrupted; reference incomplete)

〔11〕(Content appears corrupted; reference incomplete)

〔12〕(Content appears corrupted; reference incomplete)

〔13〕Kong Xiangwei, Tao Jianhong. Change of extreme temperature and precipitation events in Gansu Province in summer in recent 51 years〔J〕. Arid Zone Research, 2012, 29(6): 965-971.

〔14〕Yang Jianlin, Feng Jianming, Yan Jun, et al. Ningxia high-temperature climatic characteristics and analysis of abnormal atmospheric circulation〔J〕. Journal of Desert Research, 2012, 32(5): 1417-1425.

〔15〕Guan Xuefeng, Sun Weiguo, Li Minjiao, et al. Climate change in North Xinjiang and its response to Arctic Oscillation during the period of 1965-2012〔J〕. Arid Zone Research, 2016, 33(4): 26-28.

〔16〕Gong Daoyi, Han Hui. Study on the trend of extreme weather in the summer of Beijing and China〔J〕. Acta Geographica Sinica, 2004, 59(2): 230-238.

〔17〕Fernandez-Montes S, Rodrigo F S, Seubert S, et al. Spring and summer extreme temperatures in Iberia during last century in relation to circulation types〔J〕. Atmospheric Research, 2013, 127: 154-164.

〔18〕You Q L, Kang S C, Aguilar E, et al. Changes in daily climate extremes in the eastern and central Tibetan Plateau during 1961-2005〔J〕. Journal of Geophysical Research-Atmospheres, 2011, 116(D7): 1-13.

Abstract: Climate environment is one of the most volatile factors in ecological health and sustainable social development. Temperature is important for maintaining the stability of climate system and providing a livable environment for human beings. In this study, the linear temperature trend, wavelet analysis and correlation analysis were used to analyze the change of average temperature and extreme temperature events in Ningxia during the period from 1962 to 2015. The results showed that the values of average temperature in whole Ningxia, the northern and central arid zones and the southern mountainous regions since 1962 were 0.38°C · (10a) ^{1}, 0.42°C · (10a) ^{1}, 0.36°C · (10a) ^{1} and 0.38°C · (10a) ^{1} respectively. There were the 20-32a, 8-19a and 2-7a periods of temperature fluctuation, and also the 8a and 20a sub-periods in the 13a and 32a main periods, respectively. The occurring frequency of extremely low temperature was lower than that of extremely high temperature, the duration of the former was shorter than that of the latter, the seasonal increase of low temperature was higher than that of high temperature, and the temperature fluctuation was the most significant in winter. The drought degree in Ningxia became more serious due to the increase of both average temperature and extremely high temperature, and the plant diseases and insect pests were increased because of the unbalanced climate change and the reduction of extremely low temperature, thus the ecosystems were further degenerated, so it is necessary to take some improvement measures.

Keywords: temperature; period; change trend; extreme climate index; Ningxia

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