Characteristics of Summer Climate Change in Inner Mongolia over the Past 60 Years and Its Response to El Niño (Postprint)

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Abstract

Most areas of Inner Mongolia belong to the temperate continental monsoon climate zone, characterized by climatic fragility, complexity, and diversity. As an important ecological security barrier in northern China, Inner Mongolia has experienced significant changes in summer temperature and precipitation against the background of global warming, with the region' s sensitivity to climate change becoming increasingly prominent. Based on historical observations from meteorological stations and global reanalysis data, an analysis of the variation characteristics of summer meteorological elements in Inner Mongolia over the past 60 years and their response to El Niño events yields the following conclusions: (1) Over the past 60 years, summer precipitation in most areas of central and eastern Inner Mongolia has exhibited a decreasing trend, while temperature has shown a region-wide warming trend. (2) The correlation between the winter El Niño index and meteorological elements in the following summer displays interdecadal variation characteristics; moreover, during the summer following an Eastern-type El Niño, most areas of Inner Mongolia experience above-normal precipitation and below-normal temperature; during the summer following a Central-type El Niño, northwestern Inner Mongolia experiences above-normal precipitation, while most of the central and eastern regions experience below-normal precipitation, with above-normal temperature across the entire region. (3) Analysis reveals that the primary cause of differences in summer precipitation between different types of El Niño is the differing intensity and position of the Western Pacific subtropical high, anomalous anticyclonic circulation, and mid-high latitude circulation anomalies in the two types of El Niño events. During the summer following an Eastern-type El Niño, the subtropical high is positioned south of its climatological mean, and a dual-blocking circulation anomaly occurs in the mid-high latitudes of Eurasia. The northerly airflow between the low trough cold vortex and the upstream blocking high causes moisture from the Arctic Ocean and Pacific moisture from the western side of the subtropical high to converge over North China and transport northeastward, resulting in anomalously abundant precipitation in Inner Mongolia. For the Central-type, the subtropical high is positioned west and north of its climatological mean, causing southerly moisture to turn eastward, while mid-high latitude anticyclonic circulation anomalies are unfavorable for moisture transport from high latitudes, reducing moisture transport to most areas of Inner Mongolia and resulting in below-normal precipitation. (4) Moisture transport by the Indian summer monsoon, induced by Indian Ocean sea surface temperature anomalies during the summer following the two types of El Niño events, also exerts a considerable influence on summer precipitation in Inner Mongolia.

Full Text

Characteristics of Summer Climate Change and Its Response to El Niño in Inner Mongolia During the Past 60 Years

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Abstract: Most areas of Inner Mongolia belong to the temperate continental monsoon climate zone, characterized by climatic fragility, complexity, and diversity. As an important ecological security barrier in northern China, the region has experienced significant changes in summer temperature and precipitation against the backdrop of global warming, with increasing sensitivity to climate change. Based on historical meteorological observations and global reanalysis data, this study analyzes the characteristics of summer meteorological elements and their responses to El Niño events in Inner Mongolia over the past 60 years. The main conclusions are as follows: (1) During the past 60 years, summer precipitation in most parts of central and eastern Inner Mongolia has shown a decreasing trend, while temperature has increased across the entire region. (2) The correlation between winter El Niño indices and meteorological elements in the subsequent summer exhibits interdecadal variation characteristics. In the summer following eastern Pacific (EP) El Niño events, most areas of Inner Mongolia experience above-normal precipitation and below-normal temperature. In contrast, the summer following central Pacific (CP) El Niño events features above-normal precipitation in northwestern Inner Mongolia, below-normal precipitation in most central and eastern regions, and above-normal temperature across the entire region. (3) The primary cause of precipitation differences between the two El Niño types lies in the varying intensity and position of the Western Pacific subtropical high, anomalous anticyclonic circulation, and mid-to-high latitude circulation anomalies. In the summer following EP El Niño events, the subtropical high shifts southward compared to normal years, while a double-blocking circulation anomaly pattern emerges over the Eurasian mid-to-high latitudes. The northerly airflow between the low-trough cold vortex and the upstream blocking high facilitates the convergence of Arctic Ocean moisture and Pacific moisture on the western side of the subtropical high over North China, which is then transported northeastward, resulting in anomalously high precipitation in Inner Mongolia. For CP El Niño events, the subtropical high shifts westward and northward, causing southern moisture to turn eastward, while mid-to-high latitude anticyclonic circulation anomalies are unfavorable for moisture transport from high latitudes, reducing moisture transport across most of Inner Mongolia and resulting in below-normal precipitation. (4) Water vapor transport associated with the Indian summer monsoon, induced by Indian Ocean SST anomalies in the subsequent summer, also plays a considerable role in Inner Mongolia’ s summer precipitation.

Keywords: climate change; temperature; precipitation; El Niño; monsoon; Inner Mongolia

1 Introduction

Inner Mongolia is located in the northern border of China, spanning the Northeast, North China, and Northwest regions, and is dominated by a temperate continental monsoon climate. The region serves as a crucial ecological security barrier in northern China, with its ecological safety affecting not only local livelihoods and socio-economic development but also the ecological security of North China, Northeast China, Northwest China, and even the entire nation. In recent years, global climate warming has altered atmospheric circulation patterns, impacting regional climate. Numerous studies have shown that precipitation has decreased across large areas of Inner Mongolia over recent decades, particularly in central and southeastern regions, while the regional average temperature has risen continuously with fluctuations. Research indicates that the average annual precipitation in Inner Mongolia from 1961 to 2018 showed a decreasing trend, while spatially exhibiting an increasing pattern from southeast to northwest. Summer precipitation in Inner Mongolia also demonstrates significant interdecadal variation characteristics, with a transition from less to more precipitation around the mid-1970s, followed by a shift to less precipitation after the mid-1990s, and periodic variations of 5-7 years. Analysis of factors influencing summer precipitation in Inner Mongolia reveals that the main factors include atmospheric circulation and sea surface temperature (SST) in the preceding winter and concurrent spring.

El Niño represents the strongest interannual variability signal of tropical ocean-atmosphere interaction and significantly influences the East Asian monsoon system and China’ s climate. Studies have shown that El Niño’ s lagged effect on East Asian atmospheric circulation and Chinese summer precipitation manifests as increased summer precipitation in the Yangtze River basin and decreased precipitation in the Huai River basin. In the decaying summer of El Niño events, anomalous anticyclones cause the subtropical high to strengthen and extend westward, with substantial water vapor transport from the western Pacific leading to increased precipitation in the Yangtze River basin. Since the 1980s, the probability of CP El Niño events, characterized by warm SST anomalies in the central equatorial Pacific, has increased significantly. Due to different SST anomaly distributions, EP and CP El Niño events produce different atmospheric responses and consequently different impacts on China' s climate. Zhang Renhe et al. attributed the impact of El Niño events on Chinese summer precipitation primarily to the anomalous western North Pacific anticyclone, with differences between the two El Niño types mainly arising from changes in the anticyclone' s position. In the summer following EP El Niño events, the westward extension of the subtropical high leads to synchronized increases in precipitation in northern China and the Yangtze River basin. In contrast, during the summer following CP El Niño events, the anomalous anticyclone circulation shifts northward, with strong water vapor transport on its western side causing significantly increased precipitation in the Jianghuai region.

Historical lagged responses of Inner Mongolia' s climate to El Niño events show that besides significant precipitation anomalies in southern China, Inner Mongolia also experiences notable precipitation anomalies. For example, in the year following the 1997/1998 super EP El Niño event (1998), precipitation across Inner Mongolia was anomalously high, while in the year following the 2009/2010 CP El Niño event (2010), flood season precipitation was anomalously low. These studies and observations demonstrate that El Niño events significantly impact precipitation in Inner Mongolia, with different types of El Niño events producing different effects. Therefore, this study investigates the characteristics of climate change in Inner Mongolia over the past 60 years and its lagged response to two types of El Niño events, aiming to identify the influence mechanisms of El Niño on Inner Mongolia' s climate and improve flood season climate prediction capabilities, which is of great significance for disaster prevention and mitigation in the region.

1.1 Data Sources This study utilizes: (1) Monthly gridded dataset of surface precipitation and temperature in China (V2.0) with $0.5° \times 0.5°$ resolution, provided by the National Meteorological Information Center. This dataset is based on China' s surface station data compiled by the National Meteorological Information Center' s Basic Data Special Project and interpolated using the ANUSPLIN software' s thin-plate spline method. (2) Monthly mean reanalysis data of upper-air fields and wind fields from the National Centers for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) with $2.5° \times 2.5°$ horizontal resolution. (3) Monthly SST data from the Extended Reconstructed Sea Surface Temperature version 5 (ERSST.v5) provided by the National Oceanic and Atmospheric Administration (NOAA). (4) Monthly El Niño indices from the Climate Prediction Center (CPC).

1.2 Research Methods Following the definitions of EP and CP El Niño indices by Ren et al. (2011), the Nino3 (150°W-90°W, 5°S-5°N) and Nino4 (160°E-150°W, 5°S-5°N) indices are defined as area-averaged SST anomalies. The EP and CP El Niño indices are calculated as:

$$\text{NinoEP} = \text{Nino3} - 0.5 \times \text{Nino4}$$

$$\text{NinoCP} = \text{Nino4} - 0.5 \times \text{Nino3}$$

Using the criterion that Nino3 $\times$ Nino4 $>$ 0, and referencing the historical El Niño event statistics published on the official website of China' s National Climate Center, we identified 10 EP El Niño events and 9 CP El Niño events during 1961-2020 (Table 1). EP El Niño events are generally stronger than CP events, with the 1997/1998 super EP El Niño event being particularly notable.

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2 Results

2.1 Climate Change Characteristics Figure 1 shows the climatological spatial distribution of summer precipitation and temperature in Inner Mongolia. Summer average precipitation ranges from 18-120 mm, generally increasing from west to east. Precipitation in some western parts of Alxa League is below 18 mm, while the maximum precipitation in eastern Hulunbuir exceeds 120 mm. Temperature shows a decreasing trend from southwest to northeast, with summer average temperatures ranging from 14-28°C. Most western areas of Inner Mongolia have summer average surface temperatures above 24°C, while northeastern Hulunbuir has temperatures below 14°C.

The spatial distribution of interannual trends in summer precipitation and temperature from 1961 to 2020 (Figure 1) reveals that, except for western and northeastern Inner Mongolia, most central and eastern regions show an overall decreasing precipitation trend, with the most significant reduction in the southeastern area reaching -0.3 $\text{mm} \cdot \text{a}^{-1}$, significant at the 95% confidence level. From an interdecadal perspective, regional average summer precipitation showed fluctuating increases during the 1960s-1970s, transitioned to less precipitation after entering the 21st century, with a linear trend of -0.04 $\text{mm} \cdot \text{a}^{-1}$ for the entire period. Temperature shows a significant warming trend across the region, particularly in north-central and eastern Inner Mongolia where warming reaches 0.04°C $\cdot\, \text{a}^{-1}$. The regional average warming rate is 0.03°C $\cdot\, \text{a}^{-1}$. From an interdecadal perspective, temperatures across the region have risen significantly since the beginning of the 21st century.

2.2 Correlation Between El Niño Indices and Precipitation/Temperature The spatial distribution of correlation coefficients between winter NinoEP/NinoCP and precipitation/temperature in the subsequent summer is shown in Figure 2. Winter NinoEP shows positive correlations with summer precipitation across most of Inner Mongolia, except for parts of the northeast and southwest, with correlations in eastern regions passing significance tests. The correlation between NinoCP and precipitation is not uniform, with negative correlations in east-central and western-eastern areas, and positive correlations elsewhere, though the correlation with regionally averaged precipitation is only 0.10, not statistically significant.

The correlation between winter NinoEP and summer temperature is more consistent, showing negative correlations across most of Inner Mongolia, though not statistically significant. The correlation between winter NinoCP and summer temperature is positive across most of the region, particularly in western Hulunbuir where correlations pass significance tests. The correlation with regionally averaged temperature is 0.20, also not statistically significant.

The 11-year running correlation coefficients between winter NinoEP/NinoCP and summer precipitation/temperature in Inner Mongolia (Figure 3) reveal significant interdecadal variation. The correlation between NinoEP and precipitation shifted from positive to negative in the late 1970s, became significantly positive in the early 21st century, and turned negative again in recent years. The correlation between NinoCP and precipitation also shows interdecadal fluctuations but is less significant. The correlation between NinoEP and temperature shifted from positive to negative in the mid-1970s, while the correlation between NinoCP and temperature shifted from negative to positive in the early 1970s, back to negative in the early 21st century. Previous studies have shown that the relationship between El Niño and the South Asian summer monsoon exhibits interdecadal variation, suggesting that the lack of statistical significance in the correlations may be due to the interdecadal nature of El Niño' s influence on Inner Mongolia' s climate.

Composite analysis of the 10 EP El Niño events (Table 1) shows that, except for 2006/2007 when precipitation was below normal, the other nine EP events produced above-normal precipitation, particularly the 1997/1998 super El Niño event when the precipitation anomaly percentage reached 39.12%. The composite precipitation anomaly for all EP events is 9.91%. Among the nine CP El Niño events, four produced above-normal precipitation while five showed significantly below-normal precipitation, particularly in 2004/2005 when precipitation decreased by 40.63%. The composite precipitation anomaly for CP events is -4.67%.

Temperature anomalies show more consistent patterns. In the summer following EP El Niño events, most of Inner Mongolia experiences below-normal temperatures, with a composite anomaly of -0.27°C. In contrast, CP El Niño events produce above-normal temperatures across the region, particularly in north-central areas where temperatures are 0.6°C above normal, with a composite anomaly of 0.40°C. Notably, temperature anomalies in both EP and CP events became positive after 2009/2010, possibly related to global warming.

2.3 Possible Impacts of El Niño Events on Inner Mongolia' s Climate

The spatial distribution of precipitation anomaly percentages (Figure 4) shows that EP El Niño events cause above-normal summer precipitation across most of Inner Mongolia, particularly in western regions where precipitation exceeds 20% above normal. In contrast, CP El Niño events produce a more scattered pattern, with below-normal precipitation in central and western-eastern regions, and above-normal precipitation only in the northwest and far east. Temperature anomalies (Figure 4) are more consistent across the region, with EP El Niño events producing below-normal temperatures and CP events producing above-normal temperatures.

Precipitation is directly related to sustained water vapor transport and divergence. Figure 5 presents composite analyses of vertically integrated water vapor flux and its divergence, radial and zonal transport, and atmospheric precipitable water for the summers following EP and CP El Niño events. In the summer following EP El Niño (Figure 5), the western Pacific exhibits anomalous anticyclonic and cyclonic circulation patterns from south to north. The western side of the anomalous anticyclone near 20°N carries abundant water vapor from the western Pacific to the Yangtze River basin and areas northward. Meanwhile, the anomalous anticyclone-cyclone circulation structure over Eurasian mid-to-high latitudes facilitates moisture transport from the Arctic Ocean and high latitudes to northwestern inland areas, where it converges with Pacific moisture over North China and is transported northeastward. The radial water vapor transport anomaly shows a negative center west of Lake Baikal (Figure 5), indicating northerly moisture transport to northwestern and North China, while most of eastern China shows significant positive anomalies, indicating strong southerly moisture transport to North China and Northeast China. The zonal water vapor transport anomaly reveals that the subtropical jet stream is located near 40°N, with its axis showing a meridional span of approximately 10° longitude, and westerly moisture transport in North China is significantly enhanced, with atmospheric precipitable water showing significant positive anomalies, resulting in abundant summer precipitation across most of Inner Mongolia.

In the summer following CP El Niño events (Figure 5), the anomalous anticyclone over the western North Pacific is positioned further north and is stronger than in EP events, with its northern edge reaching near 30°N. Its western side transports large amounts of low-latitude moisture to the Jianghuai River basin, forming a significant anomalous moisture convergence center that then turns eastward toward Japan. Meanwhile, the anomalous anticyclone near Lake Baikal is unfavorable for moisture transport from the Arctic Ocean and high latitudes to North China. The radial water vapor transport results show that southerly moisture transport in North China is significantly weaker (Figure 5), indicating reduced moisture transport from low latitudes. Additionally, the subtropical upper-level jet is positioned further north (Figure 5), with its axis near 45°N and weakened intensity. The region with wind speeds $ $30m \cdot s^{-1} has a meridional span of about 5° longitude, and the jet axis tilts southeastward over North China, reducing westerly moisture transport. Inner Mongolia experiences anomalous easterly moisture transport, and atmospheric precipitable water shows negative anomalies across most of central-eastern Inner Mongolia, leading to below-normal precipitation.

The Western Pacific subtropical high is a crucial system affecting moisture transport paths in eastern China. Different types of El Niño events influence the position and intensity of the subtropical high through ocean-atmosphere interactions. The 5880 gpm contour positions at 500 hPa for individual EP and CP El Niño events (Figure 6) show large variations in subtropical high position among different EP events. In the three super EP events (1982/1983, 1997/1998, and 2014/2016), the subtropical high strengthened and extended significantly westward. After compositing all EP events, the subtropical high ridge line is slightly south of its climatological position. The 500 hPa height anomaly (Figure 7) shows a "+, -, +" East Asia-Pacific teleconnection pattern over the western Pacific and East Asia, favoring moisture transport from the Pacific to the Yangtze River basin and causing above-normal precipitation there. Over Eurasian mid-to-high latitudes, the "+, -, +" height anomaly distribution from the Ural Mountains to Lake Baikal to the Sea of Okhotsk favors the formation of a northern water vapor transport channel, bringing moisture from the Arctic Ocean and Eurasian high latitudes to northern China. The strong low-trough cold vortex south of Lake Baikal facilitates transport of moisture from high latitudes and southwestern moisture from the Pacific to North China, enhancing anomalous vertical ascent and favoring precipitation in North China and Inner Mongolia.

In the summer following CP El Niño events, the subtropical high is significantly weaker and retreats eastward compared to normal years and EP events. After compositing all CP events, the subtropical high ridge line is westward and northward of normal (Figure 6). The anomalous anticyclone circulation over the western Pacific is also positioned further north (Figure 5), allowing large amounts of moisture on the western side of the subtropical high to be transported to the Jianghuai River basin. The 500 hPa height anomaly shows a "+, -" distribution over the western Pacific-Sea of Okhotsk region, with southwestern warm-moist air on the northwest side of the subtropical high converging with cold-moist air from the south over the Jianghuai River basin and Japan, enhancing anomalous vertical ascent and providing favorable moisture conditions for precipitation there. However, the "+, -, +" height anomaly distribution over Eurasian mid-to-high latitudes is unfavorable for moisture transport from the Arctic Ocean and high latitudes to northern China, thereby inhibiting precipitation in North China. The strengthened westward extension of the subtropical high and the positive pressure anomaly near Lake Baikal also cause above-normal summer temperatures in Inner Mongolia.

Thus, in the summer following both types of El Niño events, tropical ocean forcing and the anomalous western Pacific anticyclone circulation transport large amounts of moisture from the western Pacific and low latitudes to the Yangtze or Jianghuai River basins, causing significantly above-normal precipitation there.

However, in the summer following EP El Niño events, the double-blocking circulation anomaly over Eurasian mid-to-high latitudes synchronously enhances precipitation in North China, whereas in the summer following CP El Niño events, the "west-high-east-low" circulation pattern is unfavorable for moisture transport from the Arctic Ocean and high latitudes, resulting in relatively less precipitation in Inner Mongolia.

Studies have shown that the maintenance of the anomalous western North Pacific anticyclone (Figure 5) and the westward extension of the subtropical high (Figure 6) in the summer following El Niño events are related to anomalously warm Indian Ocean SSTs. At this time, the anomalously warm SSTs in the equatorial central-eastern Pacific weaken, while Indian Ocean SSTs rise from the following spring through summer. The westward extension of the subtropical high and the maintenance of the western Pacific anticyclone are primarily due to the lagged response of Indian Ocean SSTs, while the influence of Pacific SSTs relatively weakases. Xie et al. (2016) demonstrated that when the tropical Indian Ocean warms in summer, the weakened Indian summer monsoon water vapor transport can cause significant precipitation reduction in North China. Yang (2019) also showed that the Indian summer monsoon is significantly positively correlated with North China summer precipitation. To analyze the connection between Indian Ocean SST anomalies and Inner Mongolia summer precipitation, we calculated correlations between summer tropical Indian Ocean (20°S–20°N, 40°E–100°E) area-averaged SST anomalies and Inner Mongolia summer precipitation (Figure 8). The results show negative correlations across most of Inner Mongolia, particularly significant in the southeastern region, indicating that when the tropical Indian Ocean warms in summer, most of Inner Mongolia experiences significant precipitation deficits.

Figure 9 presents the Indian Ocean SST anomaly distributions in the summers following EP and CP El Niño events. The Indian Ocean SST anomalies induced by the two El Niño types are not consistent. EP El Niño events produce cooler Indian Ocean SST anomalies in the following summer, which strengthen Indian summer monsoon water vapor transport and favor above-normal precipitation in Inner Mongolia. In contrast, CP El Niño events produce significant Indian Ocean warming in the following summer, and the weakened Indian summer monsoon water vapor transport is unfavorable for precipitation generation in Inner Mongolia.

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3 Discussion and Conclusions

Based on China' s gridded surface observation data, ERSST.v5 SST data, and NCEP/NCAR reanalysis data, this study analyzed the characteristics of summer precipitation and temperature in Inner Mongolia from 1961 to 2020, compared differences in meteorological elements between EP and CP El Niño events, and explored the possible causes of these differences. The main conclusions are:

(1) Summer average precipitation in Inner Mongolia ranges from 18–120 mm, generally increasing from west to east, while temperature decreases from southwest to northeast, with summer averages of 14–28°C. Except for western and northeastern regions, most central and eastern areas show decreasing precipitation trends, while temperatures exhibit warming trends across the region, particularly pronounced in north-central and eastern Inner Mongolia. The linear trends for regionally averaged precipitation and temperature are -0.04 $\text{mm} \cdot \text{a}^{-1}$ and 0.03°C $\cdot\ \text{a}^{-1}$, respectively.

(2) Composite analysis reveals that EP and CP El Niño events have different impacts on summer precipitation and temperature in Inner Mongolia. EP El Niño events produce above-normal precipitation across most of Inner Mongolia and below-normal temperatures, while CP El Niño events produce above-normal precipitation only in the northwest, below-normal precipitation in most central and eastern regions, and above-normal temperatures across the entire region. After regional averaging, EP El Niño events result in 9.91% above-normal precipitation and 0.27°C below-normal temperature, while CP events result in 4.67% below-normal precipitation and 0.40°C above-normal temperature. Notably, the correlations between the EP index (NinoEP) and CP index (NinoCP) with summer meteorological elements across most of Inner Mongolia do not reach statistical significance. Analysis using 11-year running correlations suggests this may be related to significant interdecadal variation in El Niño' s influence on meteorological factors.

(3) Further analysis of circulation and moisture characteristics reveals that precipitation differences between the two El Niño types are primarily caused by different positions of the subtropical high and anomalous anticyclone circulation, which lead to varying mid-to-high latitude moisture transport. In the summer following EP El Niño events, the western Pacific subtropical high ridge is slightly south of normal, with the anomalous anticyclone' s northern edge near 20°N, favoring moisture transport to the Yangtze River basin. The "+, -, +" double-blocking pattern over Eurasian mid-to-high latitudes facilitates convergence of Arctic and Pacific moisture over North China, causing significantly above-normal precipitation in Inner Mongolia. In the summer following CP El Niño events, the subtropical high is westward and northward of normal, with the anomalous anticyclone also shifted northward, favoring moisture transport to the Jianghuai River basin. However, the "+, -, +" height anomaly pattern over mid-to-high latitudes is unfavorable for Arctic and high-latitude moisture transport to northern China, resulting in below-normal precipitation in Inner Mongolia.

(4) Indian Ocean SST anomalies in the summer following El Niño events are significantly negatively correlated with summer precipitation in Inner Mongolia, particularly in the southeastern region. The Indian Ocean SST anomalies induced by EP and CP El Niño events differ: EP events

produce cooler Indian Ocean SST anomalies that strengthen Indian summer monsoon water vapor transport and favor above-normal precipitation, while CP events produce warmer SST anomalies that weaken the Indian summer monsoon and are unfavorable for precipitation in Inner Mongolia.

This study qualitatively explains the causes of anomalous summer precipitation in Inner Mongolia through atmospheric circulation and water vapor transport analysis. It is worth noting that the anomalous changes in precipitation and temperature following both El Niño types do not reach statistical significance across most of Inner Mongolia, suggesting that the Inner Mongolia Plateau, located in the transitional zone of summer monsoon influence, is affected by other circulation systems besides El Niño. Therefore, future research should consider not only the east-west oscillation of the subtropical high caused by ocean-atmosphere interactions but also the impacts of other circulation systems, such as mid-latitude westerlies, East Asian summer monsoon, and Tibetan Plateau summer monsoon, which all warrant further consideration for improving predictions of summer precipitation in Inner Mongolia.

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