Impact of El Niño and Southern Oscillation on the summer precipitation over Northwest China

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Abstract
Using the reanalysis data and local weather station data, the relationship between El Niño and Southern Oscillation (ENSO) and the summer precipitation over Northwest China (SPNWC) is investigated. A pronounced rainfall response is observed in post-ENSO summer, especially over North Xinjiang and Yili River valley. A possible mechanism is proposed for such a seasonal lagged impact. El Niño could induce Indian Ocean warming that persists into boreal spring and summer although El Niño itself has dissipated. The warmer Indian Ocean sea surface temperature (SST) would heat the tropospheric atmosphere and elevate the tropical geopotential height at the upper level. As a result, the South Asian High (SAH) exhibits a southward extension due to the increasing geopotential height in its southern flank. A southward displacement of subtropical jet is evident associated with such SAH shift, which further induces a barotropic low pressure anomaly over central Asia. Meanwhile, associated with the southward displacement of subtropical jet, the water vapor from tropical Indian Ocean tends to transport across Iranian Plateau and bring wet and warm air into central Asia. The resultant convergence of water vapor with cold and dry air from high latitude leads to the observed rainfall anomaly to the south and east of Balkhash Lake, explaining the lagged relationship between ENSO and SPNWC. Our results have potential applications on the seasonal prediction of SPNWC.

KEYWORDS
ENSO, impact, mechanism, Northwest China, summer precipitation

1 INTRODUCTION

Northwest China is located in the inland of Eurasian continent, which is far away from the oceans. Owing to the lack of precipitation, Northwest China is featured as the arid-semiarid region. However, the interannual variation of the precipitation is pronounced in this region, especially during the boreal summer. For example, during the summer in 2016, heavy rainfall took place in the Xinjiang province over Northwest China, resulting in the severe road damages and civilian casualties. Recent studies have shown the increasing trend of such extreme precipitation since recent decades (Jiang et al., 2005; Chen et al., 2011). The economic and social loss could be reduced if skillful seasonal prediction can be provided. However, compared with the remarkable progresses in understanding the monsoonal climate over East China (e.g., reviewed by Ding and Chan, 2005), less attention is paid to the...
dynamics and predictability of the precipitation over Northwest China.

Previous studies have shown that the teleconnection patterns, such as the Silk Road pattern and Europe–China pattern are responsible for the July precipitation variations in Northwest China (Chen and Huang, 2012). The meridional teleconnection in central Asia can affect the summer rainfall over Tarim Basin in Northwest China by exciting the favorable water vapor transport (Huang et al., 2015). Significant correlation is discovered between the middle-upper tropospheric temperature and the summer rainfall over Tarim Basin (Zhao et al., 2014a; 2014b). In addition, the meridional displacement of subtropical westerly jet (Yang and Zhang, 2008; Zhao et al., 2014a; 2014b), the anomalous cyclone over central Asia (Yang and Zhang, 2007), previous thermal anomaly over Tibetan Plateau (Zhao et al., 2016) and the variation of South Asian High (SAH) (Wang et al., 2017) are also suggested to be the controlling factors for the summer precipitation in Northwest China. These findings mainly focus on the internal atmospheric variations, teleconnections and the local land-atmosphere interactions.

El Niño and Southern Oscillation (ENSO) is the strongest climate fluctuation on interannual timescale, which can induce remote climate impacts by stimulating teleconnections (Trenberth et al., 1998). Extensive studies have pointed out the control of ENSO on the East Asian monsoon (e.g., Fu and Teng, 1988; Huang and Wu, 1989; Zhang et al., 2016), in which the strengthening of northwestern Pacific subtropical high during the El Niño decaying summer plays a key role (Wang et al., 2000; Stuecker et al., 2015; Xie et al., 2016; Li et al., 2017; Zhang et al., 2017). Northwest China lies in the “westerly dominated regime” (Huang et al., 2015), which is different from East China that controlled by monsoon circulations. However, recent evidences have shown that the summer temperature and precipitation in Northwest China is also correlated with tropical SST anomalies (Yang et al., 2010; Li et al., 2018). In this study, the observations, reanalysis data, and the results from Atmospheric Model Intercomparison Project (AMIP) are analyzed to investigate the possible relationship between the Northwestern China summer precipitation and ENSO. In addition, a possible physical mechanism is proposed.

2 | DATA AND METHODOLOGY

This study utilizes HadISST (Hadley Center Global Sea Surface Temperature data set; Rayner et al., 2006) for the observed monthly mean SST, with horizontal grid resolutions of 1° × 1° since 1870. Hadley Center/Climatic Research Unit CRU_ts4.02 is adopted to obtain the high resolution (0.5° × 0.5°) land precipitation since 1901 (Harris et al., 2014), which is verified by the station precipitation data in Xinjiang province, Northwest China since 1961. Reanalysis-1 (National Centers for Environmental Prediction–National Center for Atmospheric Research reanalysis data; Kalnay et al., 1996) is used to retrieve the fields of horizontal wind, geopotential height and humidity since 1948. A common period after 1961 is analyzed for the observational data.

As an effort to confirm the atmospheric response to ocean forcings, the Atmospheric Models Intercomparison Project (AMIP) experiment output of 22 climate models that participate in Coupled Models Intercomparison Project phase 5 (CMIP5) are analyzed in this paper (Table S1). These experiments are imposed with historical sea surface temperature (SST; Taylor et al., 2012), and the common overlay period from 1979 to 2008 is analyzed.

To focus on the interannual variability of SST, circulation and precipitation, the linear trend derived from the linear regression is removed. This is necessary, especially when studying the SST in tropical Indian Ocean, which exhibits a remarkable increasing trend (Du and Xie, 2008).

3 | RESULTS

The correlation of the summer precipitation with ENSO in previous winter is given in Figure 1. A significant correlation is evident to the south and east of Balkhash Lake (Figure 1a). Especially in North Xinjiang over Northwest China, the correlation coefficient reaches 0.5, which is comparable with the summer rainfall response to ENSO in East China (Zhang et al., 2016). This result is further confirmed by the observational weather station data. As demonstrated in Figure 1c, the summer precipitation is tightly correlated with previous Niño3.4 anomalies at the stations located around Alatao Mountain, Yili River valley and the northern periphery of the Tienshan Mountains, which is consistent with the findings using CRU reconstructions. It is also noted that the precipitation over other parts of Northwest China, such as Tarim Basin, is unaffected by previous ENSO. It implies the different mechanisms of summer rainfall formation between the southern and northern sides of Tienshan Mountain.

It is interesting that the concurrent response of North Xinjiang precipitation to ENSO is weak, with the insignificant correlation of 0.2 (Figure 1e). The robust relationship occurs in post-ENSO spring and summer. In this paper, only the summer (from June to August) precipitation is studied given the fact that the climatological mean and interannual variation is largest over Northwest China in boreal summer. Such a lagged response in post-ENSO summer is worthy of investigation since equatorial SST anomalies has disappeared then (black curve in Figure 1e). The mechanism of this two-season lagged response remains unclear. Similar lagged correlation exists for ENSO-East Asian summer monsoon relationship, which has been extensively studied
As demonstrated in Figure 1e, the Indian Ocean Basin Mode SST (defined as the averaged SST within 40°–110°E; 20°S–20°N) anomaly develops after the mature phase of ENSO and persists into the following spring and summer. Xie et al. (2009) proposed that this Indian Ocean SST anomaly acts as a capacitor that prolongs the impact of fast decaying ENSO SST and further induces the anomalous anticyclone over northwestern Pacific. Figure 1b shows that the summer precipitation over North Xinjiang is also related to with the IOBM during boreal spring. The correlation pattern generally resembles that with ENSO during previous winter (Figure 1b, d). This statistical result is not surprising, given the fact that IOBM in post-ENSO spring is highly correlated with ENSO in its mature phase (Figure 1e). Figure 2 further demonstrates the regression pattern of SST anomalies against the summer precipitation over North Xinjiang. During previous winter, the most remarkable SST anomaly is observed over the equatorial central to eastern Pacific (Figure 2a), which resembles the spatial pattern of ENSO. As ENSO decays, the correlation over the equatorial eastern Pacific drops in boreal spring and summer (Figure 2b and c). However, the consistent correlation is evident over Indo-western Pacific Ocean (Figure 2b, c), indicating the capacity effect of Indian Ocean that prolongs the influence of ENSO on the summer climate over North Xinjiang. Thus, it is necessary to investigate the mechanism of how IOBM affects the summer precipitation over Northwest China (SPNWC).

In the subtropical upper troposphere, the westerly jet is an important atmospheric circulation pattern (contours in Figure 3) which is closely related to the summer precipitation distribution in central (Schiemann et al., 2009) and East Asia (Lu, 2004). Figure 3 shows the difference of the composite zonal wind anomalies at 200 hPa between the positive and negative IOBM years. Here, the positive (negative) IOBM years is defined when the detrended IOBM index exceeding 0.5 (−0.5) SD. In the observation, the positive (negative) wind anomalies are evident to the south (north) of the climatologic jet core. This pattern indicates the pronounced southward (northward) shift with the Indian Ocean warming (cooling). This result is further examined by the AMIP experiments. With the historical Indian Ocean SST forcing, the ensemble mean of 22 AMIP models is able to produce this jet shift, although the amplitude is underestimated due to intermodal cancelation (Figure S1). Previous studies have shown that this meridional shift of jet axis,
rather than the variation of jet strength, is the leading mode of the interannual jet variation (Lin and Lu, 2005; Zhao et al., 2014a; 2014b). The location of the westerly jet, especially the active center over Caspian Sea, is critical to the SPNWC (Zhao et al., 2014a; 2014b). Figure 4 demonstrates the regression pattern of circulation and water vapor transport against the normalized Jet location index (defined as the difference between the averaged 200 hPa zonal wind within

**FIGURE 2** The regression patterns of SST anomalies against the summer rainfall over North Xinjiang in D(-1)JF (a), MAM (b) and JJA (c). The shadings indicate the regions with significant correlations at 99% confidence level.

**FIGURE 3** The summer (June to August) climatologic zonal wind (contour; unit: m/s) and the composite differences of its anomalies between the positive and negative IOBM years (shading; unit: m/s) at 200 hPa in the observation.
40°–80°E; 30°–42.5°N and 40°–80°E; 42.5°–55°N). The southward shift of the jet over Caspian Sea would stimulate a cyclonic circulation at 500 hPa (Figure 4a), which is a well-known key circulation pattern favorable for the summer precipitation over North Xinjiang. In the lower troposphere, the anomalous warm and wet air from the Indian Ocean transports across the Iranian Plateau and meets with the cold air from high latitude around the Balkhash Lake (Figure 4b). The vertical integrated water vapor transport also demonstrates the moisture convergence around the Balkhash Lake.

**FIGURE 4** The regression patterns of horizontal wind (vector; unit: m/s) and geopotential height anomalies (shading; unit: gpm) at 500 hPa (a) and 850 hPa (b) against the normalized Jet Position Index during boreal summer. (c) The regression of vertical integrated water vapor transport against the normalized Jet Position Index during boreal summer (surface to 300 hPa; unit: 10^4 g/(s m))

**FIGURE 5** (a) The correlation patterns between IOBM and the summer tropospheric (1,000–100 hPa) temperature anomalies (shading), and the climatologic (black contour) and the composites of SAH during the positive (blue contour) and negative (green contour) IOBM years in the observation. Note that SAH is indicated by the 100 hPa 16,720 gpm geopotential height here. (b) The climatologic (contour) and the composite differences of zonal wind anomalies at 200 hPa between the years with southward and northward displacement of SAH (shading) in the observation.
(Figure 4c). This moisture convergence is confirmed by replacing the NCEP reanalysis with ERA-interim reanalysis (Figure S2; Dee et al., 2011). The above mentioned circulation features associated with the jet shift resembles the general circulation characteristics for the abundant summer rainfall over north Xinjiang (Yang and Zhang, 2007).

It has been shown that the meridional shift of subtropical westerly jet is statistically connected with ENSO-induced Indian Ocean SST anomalies, which can further induce favorable circulation patterns for SPNWC. However, what is the physical mechanism behind the IOBM-jet location relationship still remains unclear. Figure 5 (shading) demonstrates the correlation patterns between the IOBM and the summer tropospheric (1,000–100 hPa) temperature anomalies. The significant correlation is evident, indicating the pronounced tropospheric heating with surface Indian Ocean warming. Huang et al. (2011) suggests that such tropospheric heating is caused by the changes in the equivalent potential temperature in the atmospheric boundary layer associated with Indian Ocean warming, which could elevates the geopotential height at the upper troposphere to the south of the SAH (SAH). As a result, the SAH exhibits a southward extension during the warming phase of Indian Ocean warming (contours in Figure 5a). Using the ensemble mean of 22 AMIP models, the tropospheric warming and southward shift of SAH can also be reproduced (Figure S3a), indicating the robustness of the mechanism proposed by Huang et al. (2011). Since SAH is the dominant circulation system over Asian continent, its southward extension could lead to the southward displacement of the subtropical jet (Lin and Lu, 2005). As shown in Figure 5b, the observed southward jet shift is associated with southward extension of SAH, which is well reproduced with the AMIP experiments (Figure S3b). Above all, we show that SAH connects the Indian Ocean SST and subtropical jet via the tropospheric heating and the consistent meridional displacement at the upper troposphere.

4 | SUMMARY AND DISCUSSION

In this article, the response of Northwest China precipitation during post-ENSO summer is studied. Both the reconstructed and station observation data show that the pronounced response occurred to the south and east of Balkhash Lake, with significant correlations in North Xinjiang and Yili River valley. This result is different from previous findings. Yang et al. (2010) studied the relations between the summer rainfall over North Xinjiang and SST anomalies. They argued that the summer rainfall over North Xinjiang is uncorrelated with ENSO. Here, we show the significant correlation between the Nino3.4 anomalies in D(−1)JF and JJA rainfall over North Xinjiang.

A possible mechanism for such seasonal lagged response is also proposed. First, the ENSO-induced tropical Indian Ocean SST anomalies persist into post-ENSO spring and summer. Second, the local tropospheric atmosphere is heated by the Indian Ocean warming, which further elevates the geopotential height at the upper troposphere. Third, the SAH exhibits a southward extension due to the increased geopotential height in its southern flank, resulting in the southward displacement of upper level circulations, such as the subtropical westerly jet. Fourth, associated with the southward shift of subtropical jet, a barotropic response of anomalous cyclonic circulation is evident over central Asia at 500 hPa. Meanwhile, the warm and wet air from the tropical Indian Ocean transports into central Asian and converges with the cold air near Balkhash Lake. This circulation configuration is favorable for the precipitation over North Xinjiang. The above mechanism is examined by using the ensemble simulation of 22 AMIP models.

Previous studies have proposed that the relationship between ENSO and East Asia summer monsoon is unstable in different periods (e.g., Wang, 2002). We also investigate whether such interdecadal variation exists regarding the impact of ENSO on Northwest China precipitation. The preliminary results show that this relationship is generally stable during 1961–2018 (Figure S4). In addition, the impacts of different El Niño flavors are compared. Similar results are obtained for two types of El Niño, in terms of their lagged impacts on the summer rainfall over Northwestern Xinjiang (figures not shown). This study could shed some light on the seasonal prediction of summer rainfall over Northwest China.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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REFERENCES

Chen, G. and Huang, R. (2012) Excitation mechanisms of the teleconnection patterns affecting the July precipitation in Northwest China. *Journal of Climate*, 25, 7834–7851.

Chen, F., Huang, W., Jin, L., Chen, J. and Wang, J. (2011) Spatiotemporal precipitation variations in the arid Central Asia in the context of global warming. *Science China Earth Sciences*, 54(12), 1812–1821.

Dee, D.P., Uppala, S.M., Simmons, A.J., Berrisford, P., Poli, P., Kobayashi, S., Andrae, U., Balmaseda, M.A., Balsamo, G., Bauer, P., Bechtold, P., Beljaars, A.C.M., van de Berg, L., Bidlot, J., Bormann, N., Delsol, C., Dragoani, R., Fuentes, M., Geer, A.J., Haimberger, L., Healy, S.B., Hersbach, H., Holm, E.V., Isaksen, L., Källberg, P., Köhler, M., Matricardi, M., McNally, A.P., Monge-Sanz, B.M., Morcrette, J.J., Park, B.K., Peubey, C., de Rosnay, P., Tavolato, C., Thépaut, J.N. and Vitart, F. (2011) The ERA-interim reanalysis: configuration and performance of the data assimilation system. *Quarterly Journal of the Royal Meteorological Society*, 137, 553–597.

Ding, Y.H. and Chan, J.C.L. (2005) The east Asian summer monsoon: an overview. *Meteorology and Atmospheric Physics*, 89, 117–142.

Du, Y. and Xie, S.P. (2008) Role of atmospheric adjustments in the tropical Indian Ocean warming during the 20th century in climate models. *Geophysical Research Letters*, 35, L08712.

Fu, C. and Teng, X. (1988) The relationship between ENSO and climate anomaly in China during the summer time. *Science Atmospheric Sinica*, 12, 133–141 in Chinese.

Harris, I., Jones, P.D., Osborn, T.J. and Lister, D.H. (2014) Updated high-resolution grids of monthly climatic observations—the CRU TS3.10 dataset. *International Journal of Climatology*, 34(3), 623–642.

Huang, R. and Wu, Y. (1989) The influence of ENSO on the summer climate change in China and its mechanism. *Advances in Atmospheric Sciences*, 6, 21–32.

Huang, G., Qu, X. and Hu, K.M. (2011) The impact of the tropical Indian Ocean on South Asian high in boreal summer. *Advances in Atmospheric Sciences*, 28, 421–432.

Huang, W., Chen, J., Zhang, X., Feng, S. and Chen, F. (2015) Definition of the core zone of the “westerlies-dominated climatic regime”, and its controlling factors during the instrumental period. *Science China Earth Sciences*, 58, 676–684.

Jiang, F., Zhu, C., Mu, G.J., Hu, R.J. and Meng, Q. (2005) Magnification of flood disasters and its relation to regional precipitation and local human activities since the 1980s in Xinjiang, northwestern China. *Nature Hazards*, 36, 307–330.

Kalnay, E., Kanamitsu, M., Kistler, R., Collins, W., Deaven, D., Gandin, L., Iredell, M., Saha, S., White, G., Woollen, J., Zhu, Y., Leetmaa, A., Reynolds, R., Chelliah, M., Ebisuzaki, W., Higgins, W., Janowiak, J., Mo, K.C., Ropelewski, C., Wang, J., Jenne, R. and Joseph, D. (1996) The NCEP/NCAR 40-year reanalysis project. *Bulletin of the American Meteorological Society*, 77, 437–471.

Li, T., Wang, B., Wu, B., Zhou T., Chang C.P., Zhang R. (2017) Theories on formation of an anomalous anticyclone in Western North Pacific during El Niño: a review. *Journal of Meteorological Research*, 31, 987–1006.

Li, C.F., Lu, R.Y., Bett, P.E., Scaife, A.A. and Martin, N. (2018) Skillful seasonal forecasts of summer surface air temperature in western China by Global Seasonal Forecast System version 5. *Advances in Atmospheric Sciences*, 35, 955–964.

Lin, Z.D. and Lu, R.Y. (2005) Interannual meridional displacement of the East Asian upper-tropospheric jet stream in summer. *Advances in Atmospheric Sciences*, 22, 199–211.

Lu, R.Y. (2004) Associations among the components of the East Asian summer monsoon system in the meridional direction. *Journal of the Meteorological Society of Japan*, 82, 155–165.

Rayner, N.A., Brohan, P., Parker, D.E., Folland, C.K., Kennedy, J.J., Vanicek, M., Ansell, T.J. and Tett, S.F.B. (2006) Improved analyses of changes and uncertainties in sea surface temperature measured in situ since the mid-nineteenth century: the HadSST2 dataset. *Journal of Climate*, 19, 446–469.

Schiemann, R., Lüthi, D. and Schär, C. (2009) Seasonality and interannual variability of the westerly jet in the Tibetan Plateau region. *Journal of Climate*, 22(11), 2940–2957.

Stuecker, M.F., Jin, F.-F., Timmermann, A. and McGregor, S. (2015) Combination mode dynamics of the anomalous Northwest Pacific anticyclone. *Journal of Climate*, 28, 1093–1111.

Taylor, K.E., Stouffer, R.J. and Meehl, G.A. (2012) An overview of CMIP5 and the experiment design. *Bulletin of the American Meteorological Society*, 93, 485–498.

Trenberth, K.E., Branstator, G.W., Karoly, D., Kumar, A., Lau, N.C. and Ropelewski, C. (1998) Progress during TOGA in understanding and modeling global teleconnections associated with tropical sea surface temperatures. *Journal of Geophysical Research: Oceans*, 103, 14291–14324.

Wang, H.J. (2002) Instability of the East Asian summer monsoon-ENSO relations. *Advances in Atmospheric Sciences*, 19, 1–11.

Wang, B., Wu, R.G. and Fu, X.H. (2000) Pacific–East Asian teleconnection: how does ENSO affect East Asian climate. *Journal of Climate*, 13, 1517–1536.

Wang, Q., Zhao, Y., Chen, F., Yang, Q. and Huang, A. (2017) Characteristics of different patterns of South Asia high and their relationships with summer precipitation in Xinjiang. *Plateau Meteorology*, 3, 1209–1220 in Chinese.

Xie, S.P., Hu, K., Hafner, J., Tokinaga, H., Du, Y., Huang, G. and Sampe, T. (2009) Indian Ocean capacitor effect on Indo–western Pacific climate during the summer following El Niño. *Journal of Climate*, 22, 730–747.

Xie, S.P., Kosaka, Y., Du, Y., Hu, K., Chowdary, J.S. and Huang, G. (2016) Indo-western Pacific Ocean capacitor and coherent climate anomalies in post-ENSO summer: a review. *Advances in Atmospheric Sciences*, 33(4), 411–432.

Yang, L.M. and Zhang, Q. (2007) Circulation characteristics of inter-annual and interdecadal anomalies of summer rainfall in northern Xinjiang. *Chinese Journal of Geophysics*, 50(2), 412–419 in Chinese.

Yang, L. and Zhang, Q. (2008) Interannual variation of summer precipitation in Xinjiang and Asian subtropical westerly jet stream. *Journal of Applied Meteorological Science*, 19, 171–179 in Chinese.

Yang, L., Yang, T., Zhao, L. and Wang, M.Z. (2010) Relationship between summer precipitation in Northern Xinjiang and sea surface temperature anomalies. *Journal of Desert Research*, 30(5), 1215–1220 in Chinese.

Zhang, W., Jin, F.F., Stuecker, M.F., Wittenberg, A.T., Timmermann, A., Ren, H.L., Kug, J.S., Cai, W. and Cane, M. (2016) Unraveling El Niño’s impact on the East Asian Monsoon
and Yangtze River summer flooding. *Geophysical Research Letters*, 43, 11375–11382.

Zhang, R., Min, Q. and Su, J. (2017) Impact of El Niño on atmospheric circulations over East Asia and rainfall in China: role of the anomalous western North Pacific anticyclone. *Science China Earth Sciences*, 60, 1124–1132.

Zhao, Y., Huang, A., Zhou, Y., Huang, D., Yang, Q., Ma, Y., Li, M. and Wei, G. (2014a) Impact of the middle and upper tropospheric cooling over Central Asia on the summer rainfall in the Tarim Basin, China. *Journal of Climate*, 27(12), 4721–4732.

Zhao, Y., Wang, M.Z., Huang, A.N., Li, H.J., Huo, W. and Yang, Q. (2014b) Relationships between the West Asian subtropical westerly jet and summer precipitation in northern Xinjiang. *Theoretical and Applied Climatology*, 116(3–4), 403–411.

Zhao, Y., Huang, A., Wang, Q. and Yang, Q. (2016) The relation between thermal anomaly contrast over the Tibetan Plateau and its surrounding areas in May and summer rainfall in northern Xinjiang. *Climatic and Environmental Research*, 21(6), 653–662 in Chinese.

**SUPPORTING INFORMATION**

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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