Journal of the Meteorological Society of Japan, Vol. 89, No. 5, pp. 563–569, 2011

DOI:10.2151/jmsj.2011-510

NOTES AND CORRESPONDENCE

Contrasting Impacts of Two-type El Niño over the Western North Pacific during Boreal Autumn

Wenjun ZHANG

Key Laboratory of Meteorological Disaster of Ministry of Education and College of Atmospheric Sciences, Nanjing University of Information Science & Technology, Nanjing, China
School of Ocean and Earth Science and Technology, University of Hawaii, Honolulu, U.S.A.

Fei-Fei JIN

School of Ocean and Earth Science and Technology, University of Hawaii, Honolulu, U.S.A.

Jianping LI

LASG, Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing, China

and

Hong-Li REN

School of Ocean and Earth Science and Technology, University of Hawaii, Honolulu, U.S.A.

(Manuscript received 24 March 2011, in final form 3 June 2011)

Abstract

This work contrasts the climatic impacts of so-called warm-pool (WP) and cold-tongue (CT) El Niño on the atmospheric circulation over the western North Pacific (WNP). It is found that the anomalous atmospheric circulation over the WNP is nearly opposite in response to these two types of El Niño events in developing autumn. A weak anomalous anticyclone appears over the WNP during CT El Niño, whereas a weak anomalous cyclone emerges in the same region during WP El Niño. These nearly opposite autumn responses of atmospheric circulation have a significant impact on East Asian climate, and southern China autumn rainfall in particular, although this contrast tends to diminish as El Niño events enter their mature phase.

1. Introduction

The El Niño-Southern Oscillation (ENSO) phenomenon has aroused widespread concern, because it has a significant influence on seasonal climate around the globe (e.g., van Loon and Madden 1981; Ropelewski and Halpert 1987). For example, ENSO con-

Corresponding author: Wenjun Zhang, College of Atmospheric Sciences, Nanjing University of Information Science and Technology, Nanjing 210044, China.
E-mail: zhangwj@nuist.edu.cn

ditions give rise to pronounced anomaly patterns in seasonal climate in China and the United States (e.g., Huang and Wu 1989; Harrison and Larkin 1998). These significant relationships between ENSO and its remote impacts are a solid basis for regional seasonal prediction. However, these relationships are likely subject to change along with changes of ENSO regime (e.g., Ren and Jin 2011).

Recent studies have indeed shown that, in addition to the conventional El Niño (referred to as cold-tongue (CT) El Niño), a new type of El Niño, referred to as warm-pool (WP) El Niño (Kug et al. 2009), has become increasingly common in recent decades. The WP El Niño, also known as the dateline El Niño (Larkin and Harrison 2005), El Niño Modoki (Ashok et al. 2007), or the central-Pacific El Niño (Kao and Yu 2009), describes a type of warm event with sea surface temperature (SST) anomalies (SSTA) confined to the central Pacific by the warm pool edge. The influence of the WP El Niño on climate is distinct from that of the conventional El Niño (e.g., Larkin and Harrison 2005; Weng et al. 2007; Cai and Cowan 2009; Feng and Li, 2011).

It is generally recognized that the interannual climatic variations over East Asia are related to the ENSO cycle (e.g., Huang and Wu 1989; Wang et al. 2000). Previous studies have indicated that the eastern-central Pacific warming has an influence on the East Asian circulation through an anomalous anticyclone over the western North Pacific (WNP) during the conventional El Niño (e.g., Wang et al. 2000). They pointed out that an anticyclone forms in the El Niño developing autumn and persists for two or three seasons. The initiation and persistence of the WNP anticyclone may be attributed to local air-sea interactions (e.g., Wang et al. 2000), and remote impacts of Indian Ocean (e.g., Watanabe and Jin 2002; Yang et al. 2007).

In this study, we also focus on the WNP atmospheric circulation associated with the WP and CT El Niño events and their related climatic impacts. Our analyses show that the WP El Niño-related SST pattern can induce an anomalous cyclonic circulation over the WNP during developing autumns, which is nearly opposite to the response during the CT El Niño. These contrasts in atmospheric circulation responses appear to be responsible for opposing impacts on southern China autumn rainfall.

2. Data and methods

The SST datasets used in this study are HadISST1 from the Hadley Center (1951–2009) (Rayner et al. 2003). Reanalysis from the National Center for Environmental Prediction (1951–2009) (Kalnay et al. 1996) and the Climate Prediction Center Merged Analysis of Precipitation (CMAP) data (1981–2009) (Xie and Arkin 1996) are used to explore the El Niño-related teleconnections. We also use monthly station rainfall data for China (1951–2009) from the China Meteorological Administration. Anomalies are defined as deviations from the climatological mean.

In the 18 El Niño autumns defined by the Climate Prediction Center, we identify nine CT El Niño years (1951, 1957, 1963, 1965, 1972, 1976, 1982, 1987, and 1997) and nine WP El Niño years (1969, 1977, 1991, 1994, 2002, 2003, 2004, 2006, and 2009) based on SSTA patterns. The events, having larger SSTA in the eastern (central) Pacific east (west) of 150°W, are classified into the CT (WP) El Niño autumns. These years have also been identified in previous studies (e.g., Larkin and Harrison 2005; Kim et al. 2009). Because of the limitations of CMAP data, only the events after 1979 are used for the El Niño composites when analyzing associated rainfall anomalies in the tropical Pacific.

3. Results

3.1 SST and the walker circulation anomalies

We first examine composites of SST, rainfall, and the Walker Circulation anomalies for the CT and WP El Niño events. The autumn (Sep–Oct–Nov) mean is mainly taken to display differences in their climatic impacts. In the case of the CT El Niño during developing autumn, large positive SSTA cover the eastern and central Pacific centered over the eastern equatorial Pacific, accompanied by negative SSTA in the western Pacific (Fig. 1a). The WP El Niño, however, is characterized by maximum SSTA near the date line during developing autumn (Fig. 1b). There are no significant cold SSTA over the western Pacific, which also differs from the CT El Niño.

Given the contrasting SSTA patterns of the two types of El Niño, the associating impacts on atmospheric circulation are supposed to be different. As shown in Figs. 1c and 1d, the anomalous Walker Circulations are very different between the two types of El Niño. During the CT El Niño developing autumn, there are anomalous atmospheric rising and wetness over the eastern and central equatorial Pacific. Anomalous atmospheric sinking is over the western equatorial Pacific, associated with anomalous dryness. Consistent with the SSTA pattern of the WP El Niño during developing autumn, the associated rising branch is shifted westward and located between 140°–170°E, with anomalous wetness in the middle and lower troposphere. The atmospheric sinking motions are dominant in the region west of 140°E and in the lower troposphere over the eastern equato-

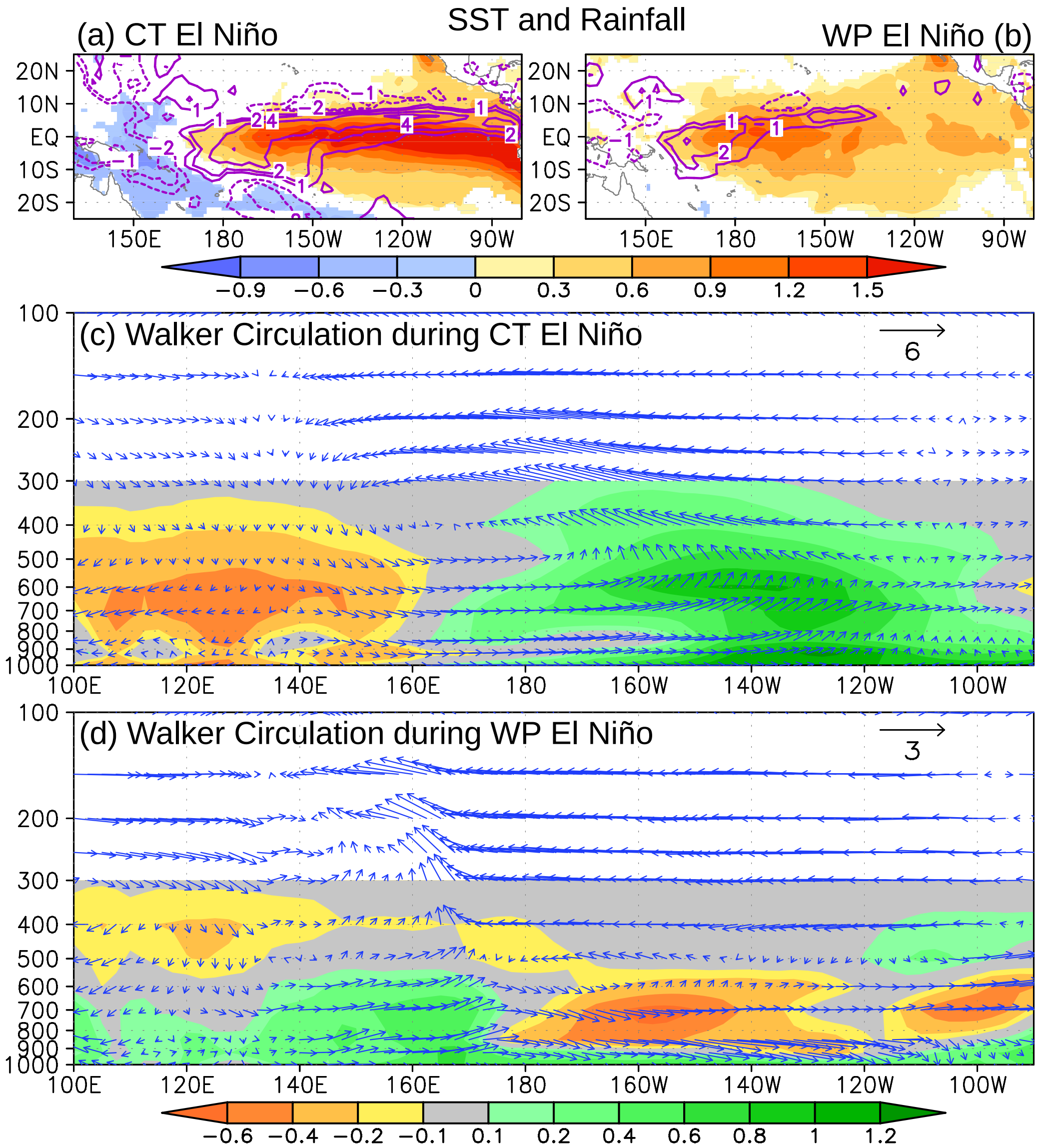

Fig. 1. Composites of SST (shaded in °C) and rainfall (contours in mm d^{-1}) anomalies for the CT (a) and WP El Niño (b). Color shading indicates that SSTA exceed 0.05 confidence level (Student's t-test). Composites of anomalous Walker Circulation averaged over 5°S–5°N based on the CT (c) and WP (d) El Niño events. The anomalous vertical velocity at the pressure levels has been multiplied by a factor of −50. The composite specific humidity is shaded in (c) and (d).

rial Pacific. Similarly, the WP El Niño-related rainfall anomaly is also shifted westward compared to the CT El Niño (Figs. 1a, b). In addition, the intensity and spatial scale of the rainfall anomaly are both smaller during the WP El Niño than those during the CT El Niño.

3.2 *Atmospheric circulation anomalies over the WNP and related impacts*

Zhang et al. (1996) speculated that suppressed convection in the western Pacific, induced by warming in the eastern Pacific, influences the circulation over the tropical western Pacific and East Asia. The impact of ENSO on the East Asian climate has been referred to

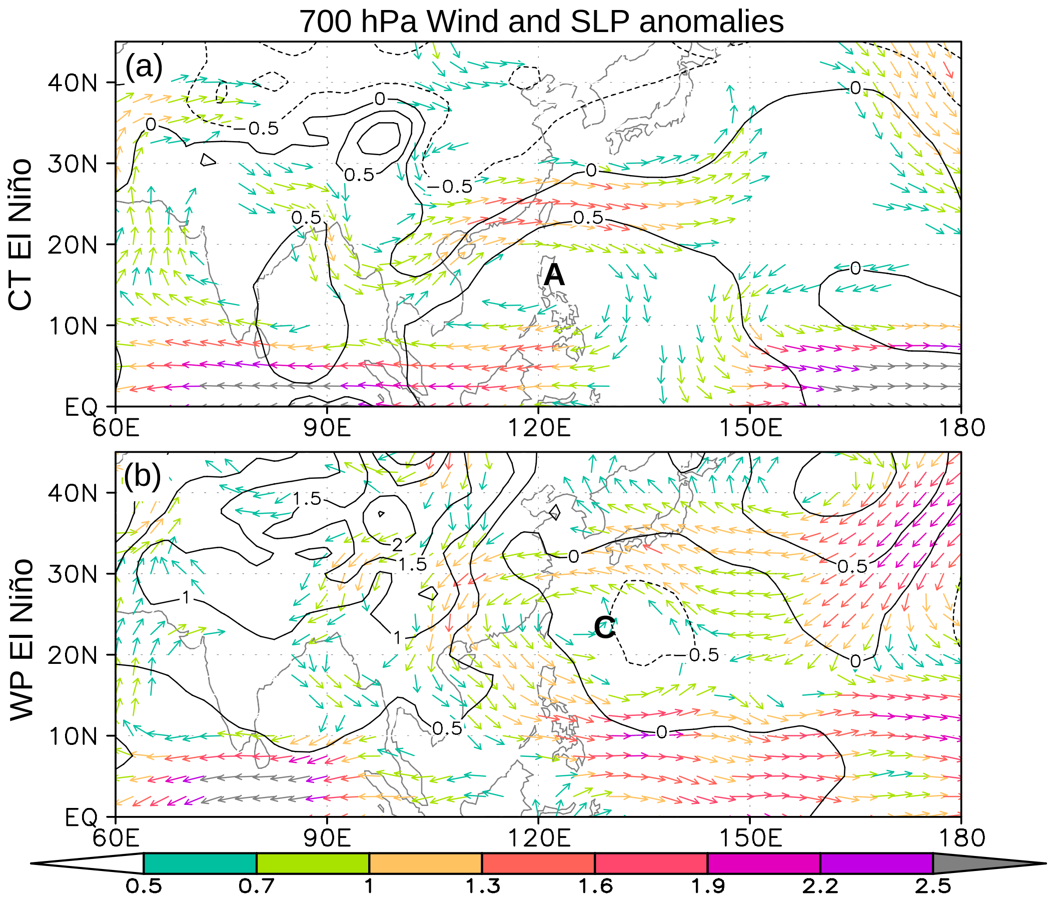

Fig. 2. Composites of wind anomalies (m s^{-1}) at 700 hPa for the CT El Niño (a) and the WP El Niño (b). "A" and "C" in the figure denote anticyclone and cyclone, respectively. Sea level pressure (SLP) anomalies (hPa) are indicated by contour lines.

as "Pacific-East Asian teleconnection", including the central Pacific cyclone, the WNP anticyclone, and the northeastern Asian cyclone (Wang et al. 2000). The WNP anticyclone is also clearly shown in Fig. 2a, based on the CT El Niño events. Because the WP El Niño is characterized by a different SSTA pattern compared to the CT El Niño, a different teleconnection pattern emerges. Along with a westward shift of the Pacific warming, the anomalous rising branch of the Walker Circulation and positive convective heating anomalies, there is an anomalous cyclone residing over the WNP instead of an anomalous anticyclone during the WP El Niño developing autumns (Fig. 2b). Associated with the cyclonic anomaly near 20°N, 130°E, anomalous northerlies prevail over southern East Asia, which is opposite to those happening during the CT El Niño autumns. Therefore, the different SST patterns during the CT and WP El Niño developing autumns result in markedly different impacts on the East Asian climate. For CT El Niño events, the southeasterly associated with the WNP anticyclone leads to a wetter-than-normal climate over southern East Asia, which is also mentioned in previous studies (e.g., Wu and Hu 2003; Niu and Li, 2008). In contrast, the northerly associated with the WP El Niño tends to cause a drier-than-normal climate over East Asia. Also, we examined the differences of the WNP atmospheric circulation anomalies between the two types of El Niño during the mature phase. It is found that the marked contrasts tend to diminish in the following season. For example, the anomalous anticyclone strengthens during the CT El Niño winters, whereas the anomalous cyclone tends to disappear and an anomalous anticyclone emerges near 120°E, 10°N during the WP El Niño winters (not shown).

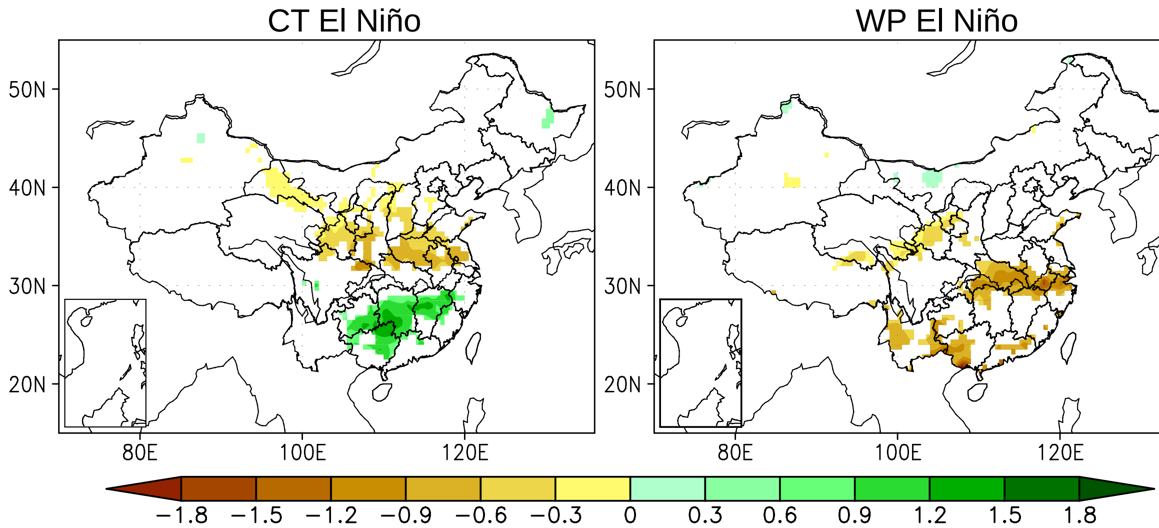

Fig. 3. Composite autumn rainfall anomaly (mm/d) pattern in China for cold tongue (CT) El Niño and warm pool (WP) El Niño events. Omitted from the figure are values that are not significant at the 0.1 confidence level (Student's *t*-test).

Figure 3 shows the autumn rainfall anomaly for the CT and WP El Niño composites. The rainfall anomalies associated with the CT El Niño show a striking dipole with a dry polarity located over northern China and a wet polarity over southern China. However, East China experiences largely dry conditions during WP El Niño autumns, with markedly dry regions in the middle and lower reaches of the Yangtze River valley and in southwestern China. The remarkable differences in rainfall anomalies between the two types of El Niño are most pronounced in southern China, where the two types have opposing influences.

3.3 Model experiments

In order to test the hypothesis that the anomalous WNP cyclonic circulation is mainly due to the associated SSTA during the WP El Niño developing autumn, the model experiments have been conducted by prescribing elliptical positive SSTA in the central Pacific (centered at 175°W) during the autumn season (Fig. 4a). This ideal SSTA pattern is similar to the central Pacific warming associated with the WP El Niño. The atmospheric general model used here is the NCAR Community Atmosphere Model version 3 (CAM3) (T42L26) (Collins et al. 2004). 10-member ensemble experiments are carried out with independent atmospheric initial conditions. Each member is initialized on February 1 and integrated for 10 months. Corresponding 10-member control experiments are conducted with prescribed seasonally-varying climatological SST.

Figure 4b shows the ensemble-mean low-level wind and SLP anomalies in autumn. Under the central Pacific warming forcing in Fig. 4a, the observed anomaly features in Fig. 2b are well captured by the simulation. In autumn, the positive SSTA in the central Pacific cause an increase in rainfall over the western and central Pacific (not shown). In association with the increasing rainfall, the enhanced convective heating excites a cyclone over the WNP, likely as a Rossby wave response (Fig. 4b). Therefore, the anomalous northerlies dominate over East Asia. In terms of SLP, low anomalies are displayed over the WNP, with high anomalies in the Indian Ocean and northern Asia. The consistence between the observation and model results leads us to deduce that the central Pacific warming associated with the WP El Niño can result in a WNP cyclone in autumn.

Previous studies have indicated that the warming in the eastern Pacific and the Indian Ocean, along with cooling in the western Pacific, all play a considerable role in the formation of the WNP anticyclone during CT El Niño developing phase by conducting model experiments (Watanabe and Jin 2002; Li et al. 2005). Similar results can also be reproduced in our modeling experiments (not shown). Therefore, different SSTA pat-

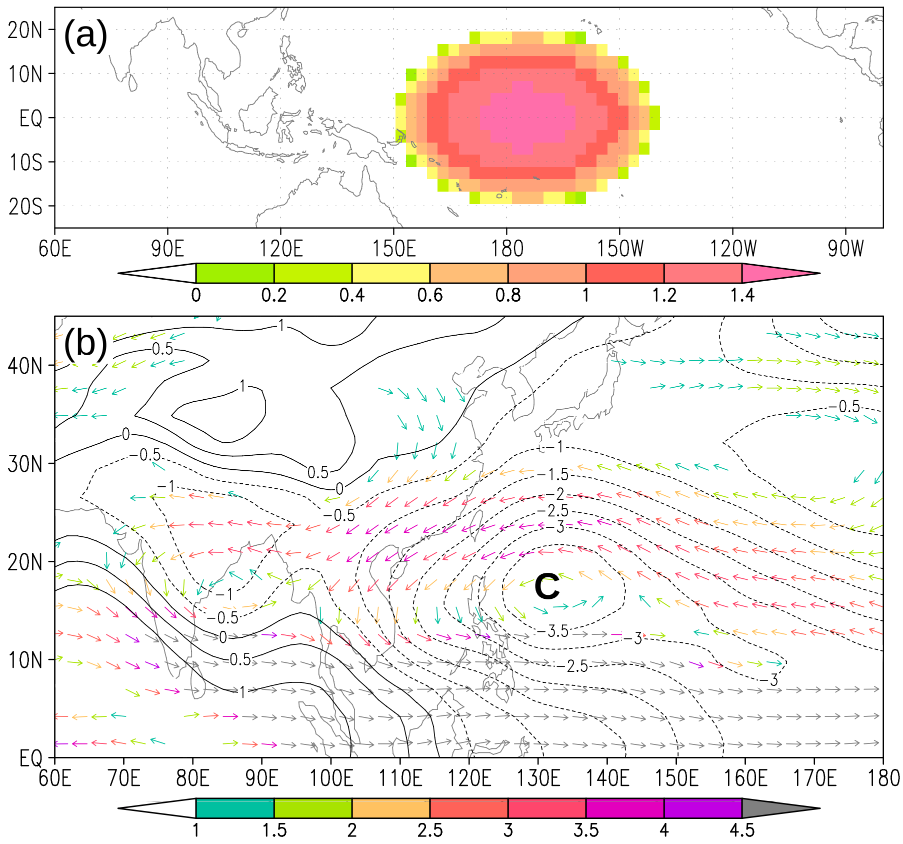

Fig. 4. (a) Specified SSTA (°C) pattern in the numerical experiment. (b) Ensemble-mean response of wind (vectors in m s^{-1}) at 700 hPa, and SLP (contours in hPa) to the central Pacific warming during autumn.

terns associated with the two types of El Niño lead to different responses in atmospheric circulation over the WNP. However, during the WP El Niño mature phase, the anomalous cyclone over the WNP tends to diminish, which is possibly related to the slightly eastward shift of positive SSTA in the central Pacific (not shown), the strengthening effect of the Indian Ocean, and impacts of the strong Asian winter monsoon.

4. Concluding remarks

The present study demonstrates that the teleconnections between Pacific warming and the climate in East Asia are different during CT and WP El Niño developing autumns. For CT El Niño events, an anomalous WNP anticyclone is the key system linking East Asian climate to eastern-central Pacific warming, as documented by Wang et al. (2000). The WNP anticyclone forms in the CT El Niño developing autumns, whereas an anomalous cyclone appears over the WNP during WP El Niño developing autumns. Our observations and model results suggested that the cyclone is a response to the WP El Niño-related SSTA in the central tropical Pacific. Consequently, the CT (WP) El Niño results in increased (decreased) rainfall over southern China in autumn because the southwesterlies (northerlies) associated with the WNP anticyclone (cyclone) bring wet (dry) air toward southern China. However, the contrast of the anomalous WNP atmospheric circulation tends to diminish as the two types of El Niño events enter their mature phase.

In recent decades, recurrent autumn droughts happen over southern China, especially the cases of severe droughts in the autumns of 2004 and 2009, which created serious drinking water problems for millions of people and damaged thousands of hectares of cropland. It is possibly associated with more frequent WP El Niño events that occurred in the late 20th century. Yeh et al. (2009) suggested that the WP El Niño would occur more frequently under global warming, which would lead to an increasing frequency of autumn droughts over southern China in a warming world.

Acknowledgements

This work is supported by the National Nature Science Foundation of China (41005049, 40805028), the National Basic Research Program "973" (Grant No. 2010CB950400), National Science Foundation grants ATM 1034798, NOAA grand NA10OAR4310200, DOE grant DESC0005110, the Priority Academic Program Development of Jiangsu Higher Education Institutions, and the National Science and Technology Support Program of China (2007BAC29B03).

References

Ashok, K., S. K. Behera, S. A. Rao, H. Weng, and T. Yamagata, 2007: El Niño Modoki and its possible teleconnection. *J. Geophys. Res.*, **112**, C11007, doi:10.1029/2006JC003798.

Cai, W., and T. Cowan, 2009: La Niña Modoki impacts Australia autumn rainfall variability. *Geophys. Res. Lett.*, **36**, L12805, doi:10.1029/2009GL037885.

Collins, W. D., P. J. Rasch, and others, 2004: Description of the NCAR Community Atmosphere Model (CAM3.0). *Technical Report NCAR/TN-464+STR*, National Center for Atmospheric Research, Boulder, Colorado, 210 pp.

Feng J., and J. Li, 2011: Influence of El Niño Modoki on spring rainfall over South China. *J. Geophys., Res.*, **116**, doi:10.1029/2010JD015160.

Harrison, D. E., and N. K. Larkin, 1998: Seasonal U.S. temperature and precipitation anomalies associated with El Niño: Historical results and comparison with 1997–98. *Geophys. Res. Lett.*, **25**, 3959–3962.

Huang, R. H., and Y. F. Wu, 1989: The influence of ENSO on the summer climate change in China and its mechanism. *Adv. Atmos. Sci.*, **6**, 21–32.

Kalnay, E. et al., 1996: The NCEP/NCAR 40-year reanalysis project. *Bull. Amer. Meteor. Soc.*, **77**, 437– 471.

Kao, H.-Y., and J.-Y. Yu, 2009: Contrasting eastern-Pacific and central-Pacific types of ENSO. *J. Climate*, **22**, 615–632.

Kim, H.-M., P. J. Webster, and J. A. Curry, 2009: Impact of shifting patterns of Pacific Ocean warming on North Atlantic tropical cyclones. *Science*, **325**, 77–80.

Kug, J.-S., F.-F. Jin, and S.-I., An, 2009: Two types of El Niño events: Cold tongue El Niño and warm pool El Niño. *J. Climate*, **22**, 1499–1515.

Larkin, N. K., and D. E. Harrison, 2005: On the definition of El Niño and associated seasonal average U.S. weather anomalies. *Geophys. Res. Lett.*, **32**, L13705, doi:10.1029/2005GL022738.

Li, T., Y. C. Tung, and J. W. Hwu, 2005: Remote and local SST forcing in shaping Asian-Australian monsoon anomalies. *J. Meteor. Soc. Japan*, **83**, 153–167.

Niu, N., and J. Li, 2008: Interannual variability of autumn precipitation over South China and its relation to atmospheric circulation and SST anomalies. *Adv. Atmos. Sci.*, **25**, 117–125.

Rayner, N. A., D. E. Parker, E. B. Horton, C. K. Folland, L. V. Alexander, D. P. Rowell, E. C. Kent, and A. Kaplan, 2003: Global analyses of sea surface temperature, sea ice, and night marine air temperature since the late nineteenth century. *J. Geophys. Res.*, **108**, No. D14, 4407, doi:10.1029/2002JD002670.

Ren, H.-L., and F.-F. Jin, 2011: Niño indices for two types of ENSO. *Geophys. Res. Lett.*, **38**, L04704, doi:10.1029/2010GL046031.

Ropelewski, C. F., and M. S. Halpert, 1987: Global and regional scale precipitation patterns associated with the El Niño/Southern Oscillation. *Mon. Wea. Rev.*, **115**, 1606–1626.

Van Loon, H., and R. A. Madden, 1981: The Southern Oscillation. Part I: Global associations with pressure and temperature in northern winter. *Mon. Wea. Rev.*, **109**, 1150–1162.

Wang, B., R. Wu, and X. Fu, 2000: Pacific-East Asian teleconnection: How does ENSO affect East Asian climate? *J. Climate*, **13**, 1517–1536.

Watanabe, M., and F. F. Jin, 2002: Role of Indian Ocean warming in the development of Philippine Sea anticyclone during ENSO. *Geophys. Res. Lett.*, **29**, doi:10.1029/2001GL014318.

Weng, H., K. Ashok, S. K. Behera, S. A. Rao, and T. Yamagata, 2007: Impacts of recent El Niño Modoki on dry/wet conditions in the Pacific rim during boreal summer. *Climate Dyn.*, **29**, 113–129.

Wu, R., and Z. Z. Hu, 2003: Evolution of ENSO-related rainfall anomalies in East Asia. *J. Climate*, **16**, 3742–3758.

Xie, P., and P. A. Arkin, 1996: Analyses of global monthly precipitation using gauge observations, satellite estimates, and numerical model predictions. *J. Climate*, **9**, 840–858.

Yang, J., Q. Liu, S. P. Xie, Z. Liu, and L. Wu, 2007: Impact of the Indian Ocean SST basin mode on the Asian summer monsoon. *Geophys. Res. Lett.*, **34**, L02708, doi:10.1029/2006GL028571.

Yeh, S.-W., J.-S. Kug, B. Dewitte, M.-H. Kwon, B. P. Kirtman, and F.-F. Jin, 2009: El Niño in a changing climate. *Nature*, **461**, 511–514.

Zhang, R., A. Sumi, and M. Kimoto, 1996: Impacts of El Niño on the East Asian monsoon: A diagnostic study of the '86/87 and '91/92 events. *J. Meteor. Soc. Japan*, **74**, 49–62.