Interactive comment on "Multi-proxy reconstructions of May–September precipitation field in China over the past 500 years"

Feng Shi[1,2*], Sen Zhao[3,4], Zhengtang Guo[1,5,6], Hugues Goosse[2], Qiuzhen Yin[2]

[1]Key Laboratory of Cenozoic Geology and Environment, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing, 100029, China

[2]Georges Lemaître Centre for Earth and Climate Research, Earth and Life Institute, Université catholique de Louvain, Louvain-la-Neuve, 1348, Belgium

[3]Key Laboratory of Meteorological Disaster of Ministry of Education, and College of Atmospheric Science, Nanjing University of Information Science and Technology, Nanjing, 210044, China

[4]School of Ocean and Earth Sciences and Technology, University of Hawaii at Mānoa, Honolulu, HI, 96822, USA

[5]CAS Center for Excellence in Tibetan Plateau Earth Sciences, Beijing, 100101, China

[6]University of Chinese Academy of Sciences, Beijing, 100049, China

Correspondence to: Feng SHI (shifeng@mail.iggcas.ac.cn)

- In blue: referees' comments
- In black: our answers
- In black italic: what we will propose to add in the text

General comments:

This is an interesting paper which introduces a newly generated annual warm season precipitation reconstruction over China. The reconstruction is based on the point-to-point regression-based method and a dense data network including 489 tree-ring width data, 2 tree-ring isotope data, 108 drought/flood index, and 1 long-term instrumental data. The verification results show good agreements between the reconstruction and instrumental data over eastern China. The paper is in itself interesting, but its structure and language needs to be improved. Since the methodologies have been commented by another reviewer, here I mainly add some comments about the proxy records.

Response: We would like to thank the reviewer for his/her constructive review, comments, and suggestions, which have helped us to greatly improve our manuscript.

We have done our best to address the reviewer's concerns and modified the manuscript in light of the reviewer's suggestions, in particular to improve the structure and the language. Point-by-point responses to the reviewer's comments are listed below.

Major comments:

Item 1: 1. "Each record is required to be significantly correlated with one or more instrumental precipitation record at the 90% ($p < 0.1$) confidence level during the overlap period, based on both raw data and linearly detrended data."

How did you do the correlation analysis? How many nearby instrumental grid cells did you compare the proxy data with? It is surprising that all 489 tree-ring proxy records are "sensitive precipitation proxy records ".

Response: We calculated the Pearson's linear correlation coefficient between the targeted precipitation grid point and the candidate tree-ring record which is located in the range of the search radius, and select all tree-ring records that are positively and significantly related with one instrumental precipitation grid points during the period AD 1961-2000 at least ($r > 0$ and $p < 0.1$). Figure 1 shows the number of grid points that is reconstructed using each tree-ring record. e.g. a tree-ring record with "100" value means that it has significant relationship with 100 nearby instrumental precipitation grid points. This illustrates that all tree-ring records are significantly related to a precipitation grid point at least.

Thanks to your question, we have revised this statement, it is '*proxy records that can be related to precipitation in the domain studied*' not '*sensitive precipitation proxy records*', because we do not determine whether the precipitation is the major limit factor of tree-ring width chronology and use all possible predictors to extend the spatial coverage.

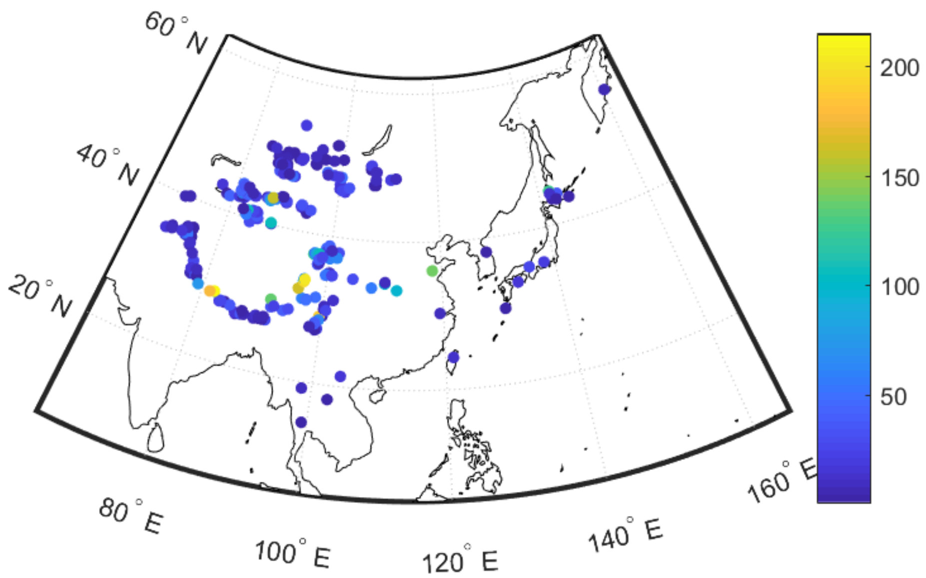

Figure 1 The number of grid points which is reconstructed using each tree-ring record.

Item 2: 2. The quality of DWI before the instrumental period needs to be discussed.

Response: Following the reviewer's suggestion, we will add two figures and a discussion on the quality of DWI in the revised manuscript. The reliability of DWI was demonstrated in Zhang (1988). Firstly, Figures 2 and 3 both show that the weakness of DWI are time discontinuity and uneven distribution (Zhang, 1988). Figure 2 is the time spans of 107 DWI records. This illustrates that most of DWI records are not continuous in time. The maximum (mean) number of missing values of 107 DWI records during the period AD 1470-2000 was 484 (161). Figure 3 shows that the number of observation of 107 DWI records during the period AD 1470-2000. A DWI record with "100" value means that it has 100 observed values during the period AD 1470-2000. This exhibits that 99 of 107 DWI records located in Eastern China (east of longitude 105°E), which is the economically developed region. There are only six DWI records to the west of longitude 100°E. The numbers of observation of these six DWI records are all less than 140. Additionally, an uncertainty due to the subjective judgment is unavoidable for the historical documentary, even though the different sources have been used to cross-validate the final reconstruction (Gong, et al., 1983; Mou, 1996; Man, 2009; Ge, 2011; Zheng et al., 2014). Moreover, the range of values is within five grades and the DFI record is not an accurate precipitation value, thus it also limits the accuracy and ability to detect the extreme events (Zheng et al., 2014).

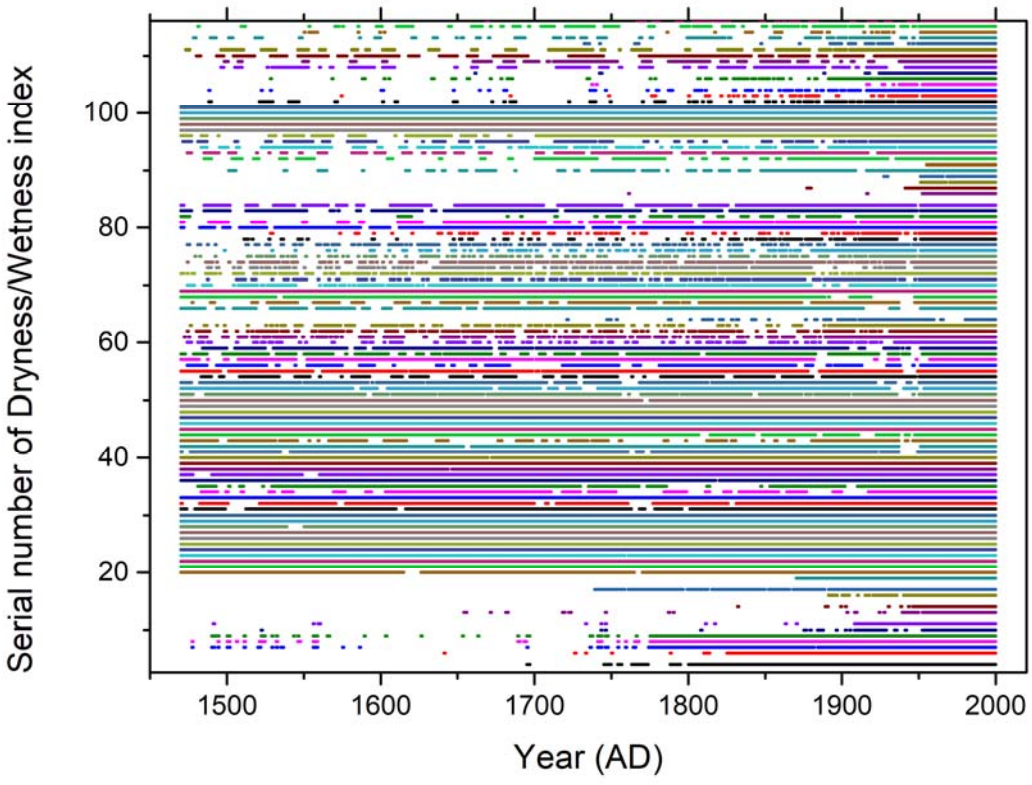

Figure 2 The time span of each Dryness/Wetness index.

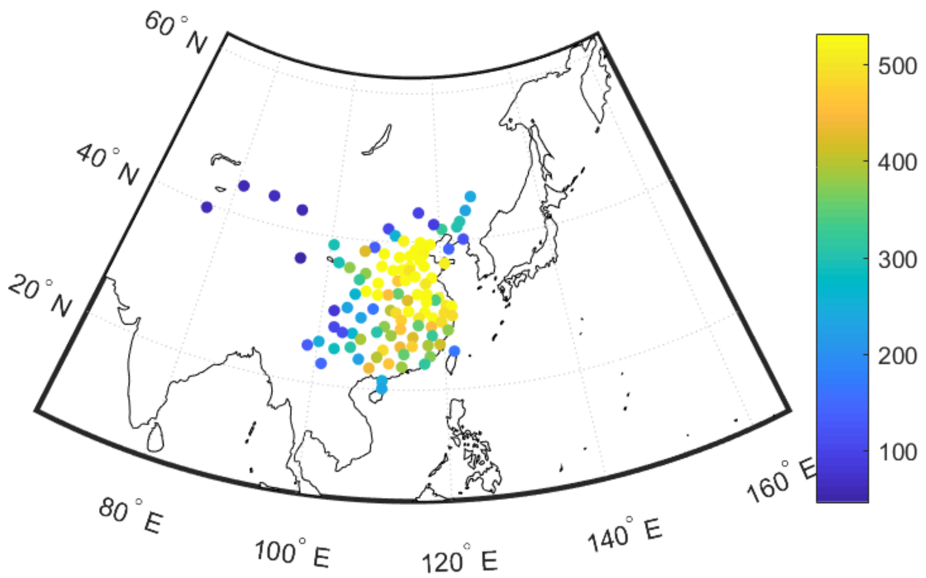

Figure 3 The number of observation of each Dryness/Wetness index during the period AD 1470-2000.

Item 3: 3. As you mentioned the precipitation/ PDSI reconstructions over East Asia from Cook et al. (2010) and Feng et al. (2013), have you compared this reconstruction with theirs?

Response: Following the reviewer's suggestion, we have calculated the correlation between Cook's PDSI reconstruction (Cook et al., 2010) with our precipitation reconstruction in Figure 4.

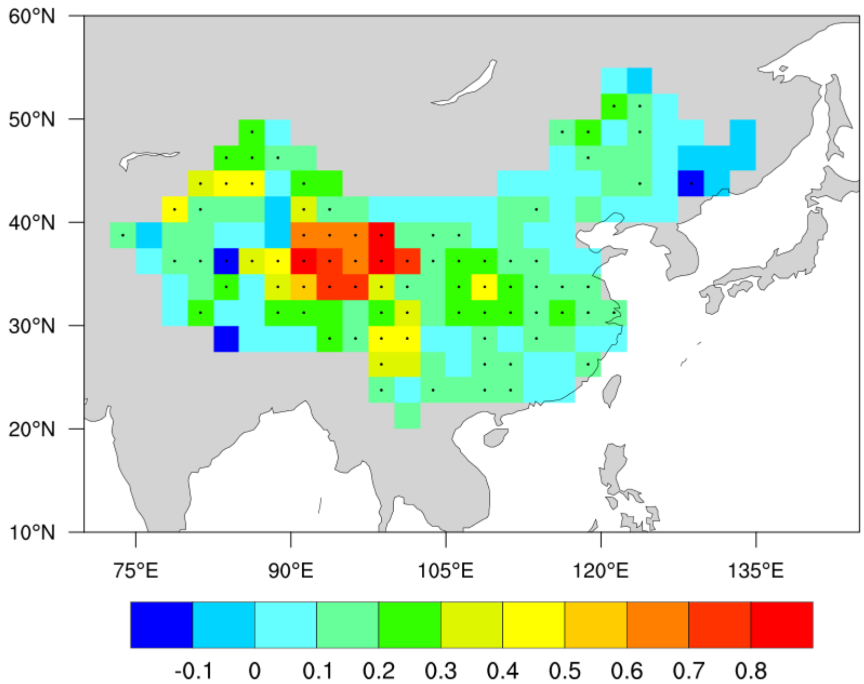

Figure 4 Spatial correlation between the PDSI reconstruction (Cook et al., 2010) and the precipitation field reconstruction obtained in this study. The dark spots mean the significant levels of the correlation coefficients at the 99% confidence level.

Figure 4 shows that the spatial correlation between them. The strong correlations appear in the Northeast Tibetan Plateau, where there are longest and most abundant tree-ring width chronologies in China. Here, the precipitation is possibly a primary control factor of the tree-ring width chronology (Yang et al., 2014b;Zhang et al., 2003). There are weak correlations between the reconstructions in Eastern China even through the correlation coefficients are significant in some regions. The Monsoon Asia Drought Atlas (MADA) is not consistent with the DWI records in Eastern China but only very few and short tree-ring width chronologies in Eastern China are used to reconstruct the MADA (Yang et al., 2013;Kang et al., 2014;Yang et al., 2014a;Zheng et al., 2014;Ge et al., 2016). We will include Figure 4 as supplementary material and discuss it in the revised manuscript.

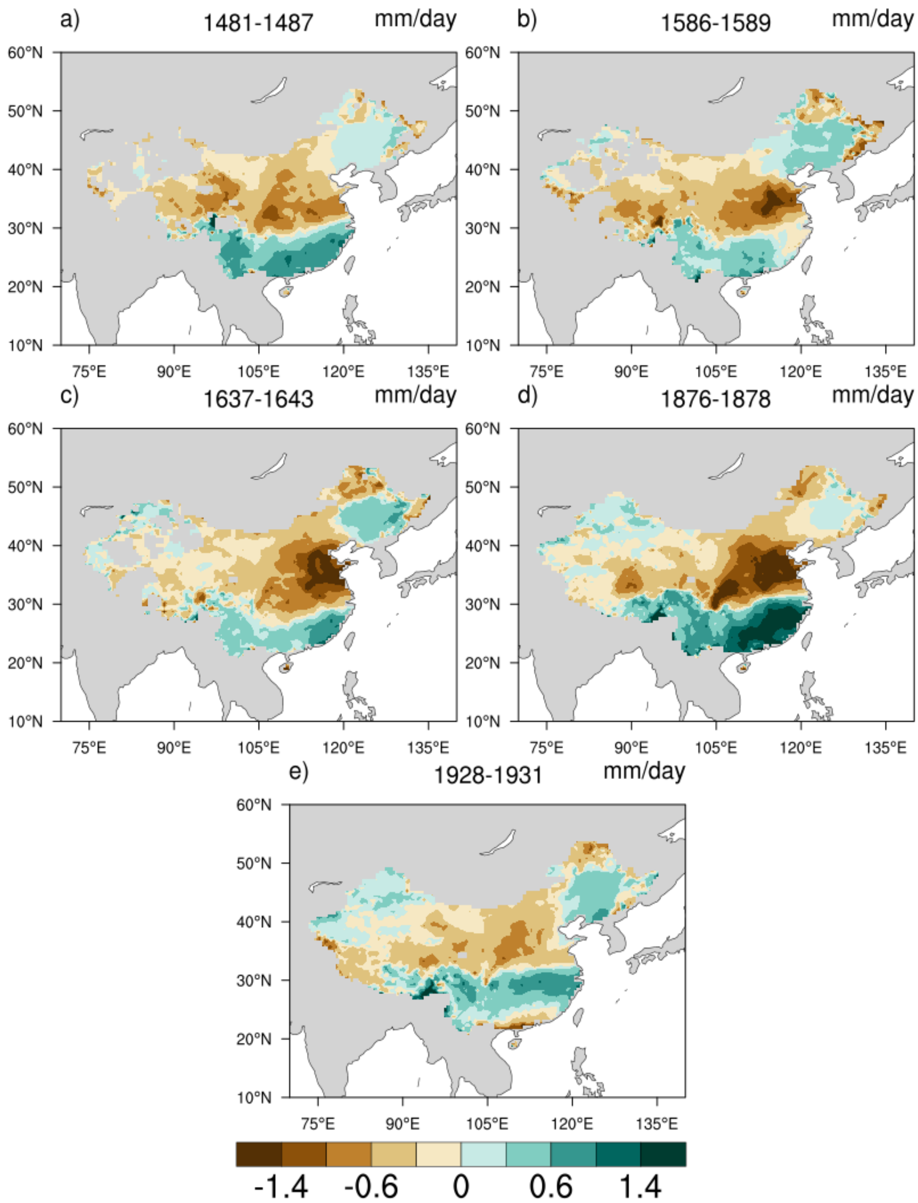

Figure 5 Spatial patterns of the May–September precipitation field relative to the 1961–90 climatological mean during five severe droughts in China.

It is a pity that the precipitation reconstruction (Feng et al., 2013) is not achieved in any published database. However, a qualitative comparison is possible for the five historical Chinese droughts in Figure 5, which will be included in the revised manuscript. The selection of five drought periods follows Feng et al. (2013). The spatial patterns of five-drought events in Figures 5a–e are different with Feng et al., (2013). A "north drought with south flooding" dipole pattern in Eastern China is seen in Figure 5a–d, and there is a triple pattern in Eastern China in Figure 5f. The similar dipole pattern can be found in Figure 5b and 5d (Feng et al., 2013) for the two drought events (AD 1586–89 and AD 1876–78). but during the above five drought periods, most of northeastern China is relatively humid situation in our study, which is not consistent with Feng et al. (2013)'s Figure 5. Moreover, the reconstruction skills are low in semiarid and arid regions (Feng et al., 2013), because there are very few tree-ring chronologies in Western China in that reconstruction. We used some tree-ring width chronologies in Western China to compensate this weakness.

Item 4: 4. "A total of 242 of 491 tree-ring chronologies were extrapolated. The maximum and mean extrapolation lengths of the 242 chronologies were 24 years and 10.5 years, respectively. The extrapolation bias was ignored because of the short extrapolation length."

As you mentioned "all tree-ring records were extrapolated to AD 2000", that means lots of infilling data are between 1981-2000CE, which overlaps with the calibration period (1981-2000CE). Have you considered using a longer calibration period and leave out the last ten years?

Response: The extrapolation is necessary for the OIE method, because we used the correlation coefficient between the candidate proxy record and the reconstructed target to weight the candidate proxy records. Following the reviewer's suggestion, we have used a longer calibration period (1961-1990) and the last ten years as the verification period (1991-2000). The corresponding contents will be revised according to the updated results.

Item 5: The second and third leading EOF patterns, the south-north dipole and the sandwich triple pattern, are indeed found in instrumental period. And they are closely related to the movement and intensity of the western pacific subtropical high (WPSH). The sea surface temperature can influence the rainfall through WPSH, but correlation maps between ENSO and summer precipitation are often noisy (Wu and Wang 2002). So, why would the signal of ENSO in rainfall be so strong in the reconstructions if it is noisy in instrumental rainfall data?

Response: This is indeed an interesting point. We cannot determine the origin of this behavior but two hypotheses can be proposed: 1) The tree-ring width chronologies in Asia are significantly related to the multiple ENSO indices (Shi et al., 2016), however, this relationship is not stable and time-varying in Figure 6 (Shi et al., 2016). We have calculated the running correlation between the 17 reconstructed ENSO indices and the precipitation anomalies averaged over Yangtze River region and Huai River region in

Figures 6a-b. We have followed Wu and Wang (2002) for the region definition. All data were filtered to obtain the interannual components when calculating running correlation coefficients using the Ensemble Empirical mode decomposition (EEMD) method, because the ENSO variability is in the interannual 3–7 year period band (Trenberth, 1997). Results indicate that the relationship between ENSO and summer precipitation in China are not stable in the reconstructions, which is consistent with the instrumental period (Wu and Wang, 2002). This indicates that different factors may affect the spatial pattern of the precipitation field, e.g. the volcanic eruption events and a more robust link is found if longer time series are analyzed. 2) The background climates states between the reconstruction period AD 1470-1849 and the instrumental period AD 1962-1993 are different. The increasing anthropogenic factor may have important influences on the precipitation field in China, e.g. the changes aerosol concentration (Li et al., 2016) and may mask some of the links between ENSO and precipitation over China. This will be discussed more explicitly in the revised version.

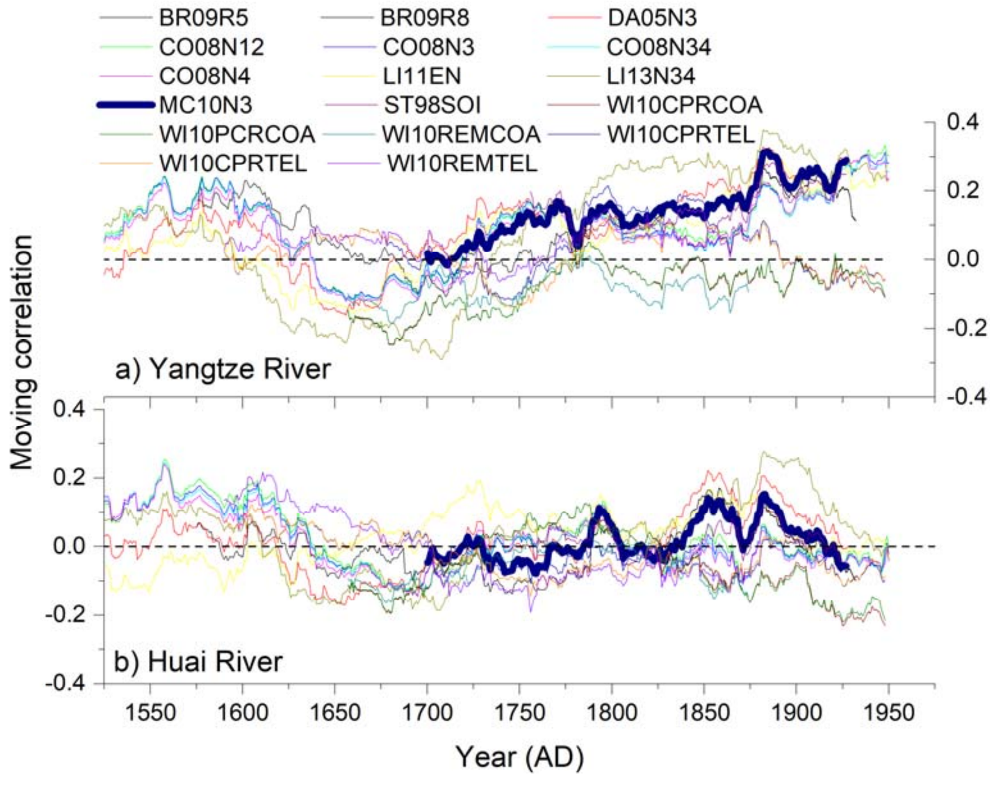

Figure 6 The 101-year running correlation coefficients of the interannual components of 17 ENSO indices with the reconstructed precipitation anomalies averaged over Yangtze River region (28°–32°N, 110°–120°E; a) and Huai River region (32.5°–35.5°N, 115°–120°E; b). The interannual components were obtained using the Ensemble Empirical mode decomposition (EEMD) method.

Moreover, we will have added the statement that the two leading EOF patterns are closely related to the western pacific subtropical high (Wu and Wang, 2002) in the revised manuscript.

Item 6: 6. In Figure 9, which method did you use for the correlation analysis? How does it look using winter temperature in the Nino 3.4 region?

Response: In Figure 9, the Pearson's sample linear cross-correlations at lag 0 is used for the correlation analysis, and the effective number of degrees of freedom is calculated following Zhao et al. (2016) to access the significance of the correlation. The unified ENSO proxy (UEP) (McGregor et al., 2010) is used to calculate the relationship between the precipitation field and the ENSO index. This index is the first PC of ten reconstructed ENSO indices, and is scaled to the instrumental HadSST1 annual mean (July–June) Niño 3.4 region sea surface temperature anomalies (McGregor et al., 2010). We will have added this explanation in the method section. Moreover, we have calculated the relationship between the previous winter (December–January–February) Niño 3.4 index and the precipitation field for each model in Figure 7. The spatial pattern is very similar with the result of annual mean Niño 3.4 index.

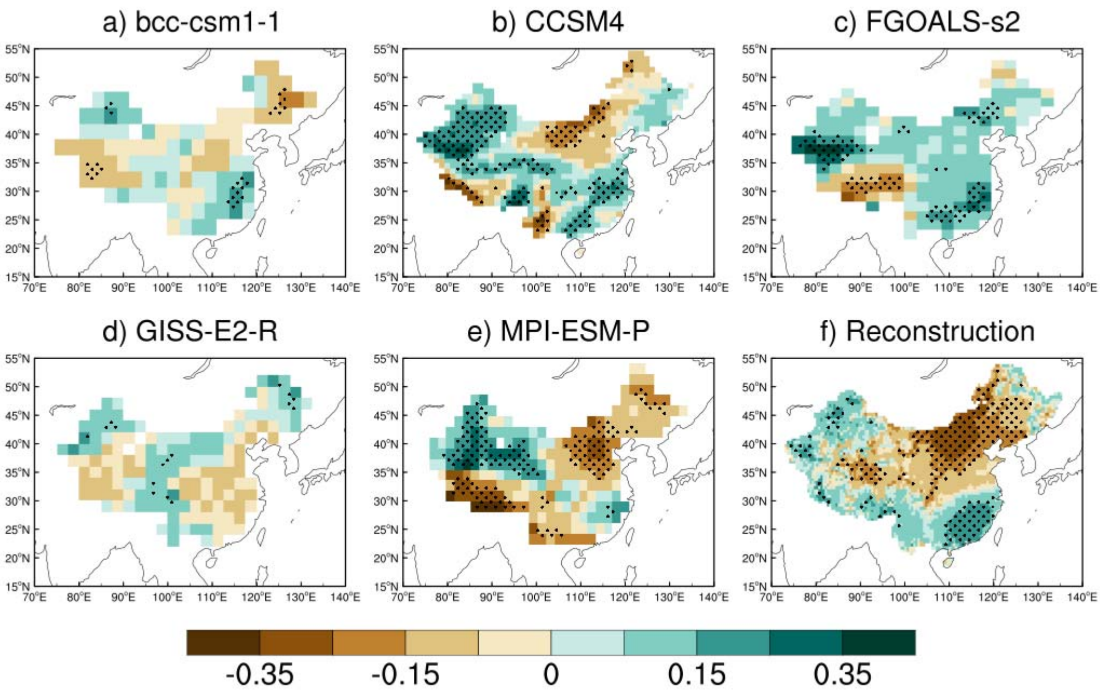

Figure 7 (a-e) Correlation maps of simulated MJJAS mean precipitation anomalies for China with the corresponding simulated preceding winter (DJF) Niño 3.4 index in five different models (bcc-csm1-1, CCSM4, FGOALS-s2, GISS-E2-R, and MPI-ESM-P). (f) Correlation maps of reconstructed MJJAS mean precipitation anomalies for China with a reconstructed annual mean ENSO index from McGregor et al. (2010).

References

Cook, E. R., Anchukaitis, K. J., Buckley, B. M., D'Arrigo, R., Jacoby, G. C., and Wright, W. E.: Asian monsoon failure and megadrought during the last millennium, Science, 328, 486-489, 2010.

Feng, S., Hu, Q., Wu, Q., and Mann, M. E.: A gridded reconstruction of warm season precipitation for Asia spanning the past half millennium, J. Climate, 26, 2192-2204, 2013.

Ge, Q.: The climate change in China during the past dynasties, Science Press, Beijing, 2011. (in Chinese)

Ge, Q., Zheng, J., Hao, Z., Liu, Y., and Li, M.: Recent advances on reconstruction of climate and extreme events in China for the past 2000 years, J. Geog. Sci. , 26, 827-854, 2016.

Gong, G., Zhang, P., Wu, X. and Zhang, J.: Research methods of historical climate change, Science Press, Beijing, 1983. (in Chinese)

Kang, S., Bräuning, A., and Ge, H.: Tree-ring based evidence of the multi-decadal climatic oscillation during the past 200 years in north-central China, J. Arid Environ., 110, 53-59, 2014.

Li, Z., Lau, W. K. M., Ramanathan, V., Wu, G., Ding, Y., Manoj, M. G., Liu, J., Qian, Y., Li, J., Zhou, T., Fan, J., Rosenfeld, D., Ming, Y., Wang, Y., Huang, J., Wang, B., Xu, X., Lee, S. S., Cribb, M., Zhang, F., Yang, X., Zhao, C., Takemura, T., Wang, K., Xia, X., Yin, Y., Zhang, H., Guo, J., Zhai, P. M., Sugimoto, N., Babu, S. S., and Brasseur, G. P.: Aerosol and monsoon climate interactions over Asia, Rev. Geophys., 54, 866-929, 2016.

Man, Z.: Climatic change historical period of China, Shandong Education Press, Jinan, 2009. (in Chinese)

McGregor, S., Timmermann, A., and Timm, O.: A unified proxy for ENSO and PDO variability since 1650, Clim. Past, 6, 1-17, 2010.

Mou, C.: Further research on the climatic fluctuations during the last 5000 years in China, China Meteorological Press, Beijing, 1996. (in Chinese)

Shi, F., Fang, K., Xu, C., Guo, Z., and P., B. H.: Interannual to centennial variability of the South Asian summer monsoon over the past millennium, Clim. Dyn., doi:10.1007/s00382-016-3493-9, 2016.

Trenberth, K. E.: The definition of el nino, Bull. Am. Meteorol. Soc., 78, 2771-2777, 1997.

Wang, P., and Zhang, D.: An introduction to some historical governmental weather records of China, Bull. Am. Meteorol. Soc., 69, 753-758, 1988.

Wu, R., and Wang, B.: A contrast of the East Asian summer monsoon–ENSO relationship between 1962–77 and 1978–93, J. Climate, 15, 3266-3279, 2002.

Yang, B., Kang, S., Ljungqvist, F. C., He, M., Zhao, Y., and Qin, C.: Drought variability at the northern fringe of the Asian summer monsoon region over the past millennia, Clim. Dyn., 43, 845-859, 2014a.

Yang, B., Qin, C., Wang, J., He, M., Melvin, T. M., Osborn, T. J., and Briffa, K. R.: A 3,500-year tree-ring record of annual precipitation on the northeastern Tibetan Plateau, Proc. Nat. Acad. Sci. U.S.A., 111, 2903-2908, 2014b.

Yang, F., Shi, F., Kang, S., Wang, S., Xiao, Z., Nakatsuka, T., and Shi, J.: Comparison of the dryness/wetness index in China with the Monsoon Asia Drought Atlas, Theor. Appl. Climatol., 114, 553-566, 2013.

Zhang, D.: The method for reconstruction of the dryness/wetness series in China for the last 500 years and its reliability, In: Zhang, J. (ed): The reconstruction of climate in China for historical times. Science Press, Beijing, 1988.

Zhang, Q., Cheng, G., Yao, T., Kang, X., and Huang, J.: A 2,326-year tree-ring record of climate variability on the northeastern Qinghai-Tibetan Plateau, Geophys. Res. Lett., 30, 1739-1742, 2003.

Zhao, S., Li, J., and Sun, C.: Decadal variability in the occurrence of wintertime haze in central eastern China tied to the Pacific Decadal Oscillation, Sci. Rep., 6, doi:10.1038/srep27424, 2016.

Zheng, J., Ge, Q., Hao, Z., Liu, H., Man, Z., Hou, Y., and Fang, X.: Paleoclimatology proxy recorded in historical documents and method for reconstruction on climate change, Quat. Sci., 34, 1186-1196, 2014. (in Chinese with English abstract)

Zheng, J., Hao, Z., Fang, X., and Ge, Q.: Changing characteristics of extreme climate events during past 2000 years in China, Prog. Geogr., 33, 3-12, 2014. (in Chinese with English abstract)

Zhang, P.: Climate change in China during historical times, Shandong Science and Technology Press, Jinan, 1996. (in Chinese)