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

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

General comments:

The manuscript presents a reconstruction of the seasonal mean precipitation in China over the past few centuries based on a collection of proxy records, comprising mostly tree-ring width and historical documents, but also included some oxygen isotopes record and a long Korean precipitation instrumental record. The statistical method to reconstruct the spatially resolved precipitation is a variant of Point-by-point regression, a method that has been applied for the generation of the Drought Atlases in other continental regions of the world by E. Cook and collaborators. I assume that other reviewers will comment on the quality and adequacy of the proxy records. Here I will mostly focus on the other aspects of the manuscript, like the statistical method applied, the interpretation of the results - connection of the reconstructed precipitation to largescale variability modes, and on the clarity of the manuscript itself.

In general terms, I think this is a valuable study. The main conclusions related to the past spatial structure of the precipitation variability, indicating the presence of spatial dipoles at decadal timescales, and the lack of a clear connection to the external forcing are interesting, although maybe to some extend to be expected, and some were already hinted at in previous studies. However, I think the manuscript itself requires some technical revisions, not dramatic, but indeed careful. The language is sometimes not specific enough and could be misinterpreted by some readers. Also, the structure of one section - the discussion-is strange. This section actually contains further results and not so much a discussion about the results. All in all, I would recommend the publication after some revisions, as specified below. Some of my points are related to language usage, but those are more recommendations to check, as I am not a native English speaker

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, we have modified the structure and the discussion following the reviewer's advice. Point-by-point responses to the comments are listed below.

Major comments:

Item 1: 1. The title could be more specific. The study reconstructs seasonal mean precipitation, so it should indicate the season

Response: The title has been revised to "*Multi-proxy reconstructions of May–September precipitation field in China over the past 500 years*" according to the reviewer's suggestion.

Item 2: 2. relationships with instrumental climate data (Fritts, 1976; Zhang, 1991). Other proxy records (e.g., ice core, coral, and varve sediment) have been introduced into regional climate field reconstructions (e.g., Neukom et al., 2011), but they are generally harder to use.

This is an example of what I meant by unspecific language, which can be also seen in other parts of the manuscript. What does 'harder to use' mean? I guess the difficulties are related to dating and time resolution, but the authors could be more specific and do not leave the reader guessing.

Response: The sentence has been revised to "*they are more difficult to be calibrated using the instrumental climate data because of their dating error and coarse time resolution.*", according to the reviewer's suggestion. Moreover, the other parts of the manuscript have also checked and polished.

Item 3: 3. The targets for reconstructions are primarily on temperature variables or variables related to temperature b

The targets are temperature or temperature-related variables.

Response: The sentence has been revised to "*The targets are primarily temperature or temperature-related variables*", according to the reviewer's suggestion.

Item 4: 4. large spatial coherency. Reconstructions of the localized precipitation field or other variables related to precipitation are seldom (Cook et al., 2004; Cook et al., 2015b; Seftigen et al., 2015) because they require proxy records with more extensive distributions. In particular, the Palmer Drought Severity Index (PDSI) Atlases over the past millennium in North America

I think the authors do not mean more extensive spatial distribution, but rather a more dense proxy network that it would be the case for temperature.

Response: The sentence has been revised to "… *because they require more dense proxy network that it would be the case for temperature.*", according to the reviewer's suggestion.

Item 5: 5. The climate field reconstruction method can be divided into the Empirical Orthogonal Function-based (EOF-based) method (Mann et al., 2009) and the point-to-point regression-based (PPR-based) method (Cook et al., 1999). The core function of the

I had real problems with this sentence. I think I understand what the authors mean, but the sentence can be really misleading. First, there are more 'families' of reconstruction methods - consider for instance the Bayesian Hierarchical Modelling Barcast, or the methods based on Canonical Correlation, or the more modern methods based on offline data assimilation (e.g. Steiger and Hakim) or even the method based on particle filters. Also, the RegEM method used by Mann et al is not really 'EOF-based. It is correct that Mann et al used an EOF pre-filtering within the RegEM method, but this is not required by the algorithm itself. Therefore, I do not think that this sentence is really correct. The authors may want to re-consider according with what I think they really want to say. They probably mean that statistical methods may include an EOF-prefiltering of the predictand or of the predictor or of both, or not pre-filtering at all. In the former case some small-scale information is lost - I think this is what the authors are pointing to.

Response: Following the reviewer's suggestion, we have rewritten the review of the reconstruction methods as proposed below:

The paleoclimate reconstruction methods are divided into the climate index reconstruction (CIR) method and the climate field reconstruction (CFR) method according to the reconstruction target. The CIRs are mainly derived from two classes of method, direct regression and indirect regression (Christiansen and Ljungqvist, 2017).The climate variables as the predictands (or dependent variable) and the proxies as the predictors (or independent variable) are called direct regression. On the contrary, the climate variables as the predictors and the proxies as the predictands are called indirect regression. The composite plus scale (CPS) method is a widely used, classic direct regression, which composites a group of proxy records using uniform or proxy-

dependent weighting. The time series obtained is then scaled to have the same variance as the targeted regional or hemispheric averaged variable over a chosen interval. The regression process is usually based on some forms of univariate or multivariate linear regression and the regression parameters are estimated using classic methods e.g. ordinary least squares, total least squares, variance matching. However, the problem is generally ill-posed because of the limited number of samples in the calibration period and regularized methods have to be introduced, e.g. truncated principal component regression (truncated-PCR) (Mann et al., 1999), Regularized Expectation Maximization (RegEM) (Mann et al., 2008), Least Absolute Shrinkage and Selection Operator (LASSO) (McShane and Wyner, 2011) and so on.

The local (LOC) method is a promising method based on indirect regression. In the novel LOC method, each proxy record should be first calibrated using the local instrumental climate data, and the time series are then averaged to obtain the large-scale mean climate index (Christiansen, 2011). An indirect regression is used in the LOC method, justified by the fact that the proxy records are functions of climate variables and not the opposite. The reconstructions based on the LOC method are assume to better preserve the low-frequency climate signal compared to other method, though they would overestimate the high-frequency signal (Christiansen and Ljungqvist, 2011). Then, the optimal information extraction (OIE) method was proposed to address this bias using the arithmetic mean of the regression coefficients of the linear regression and the inverse regression (Shi et al., 2012). The hypothesis in the OIE method is that the regression coefficients are random variables with normal distribution and vary in the ranges between the classic linear regression and inverse regression. Additional methods have also been proposed recently to take into account of some of the biases of classical methods based on regression the pairwise comparison (Hanhijärvi et al., 2013) or Bayesian method of various levels of complexity (e.g.(Tingley and Huybers, 2010)) and so on.

The CFR methods can be divided into the reduced space objective analysis-based method (Evans et al., 2001) and the point-to-point regression-based (PPR-based) method (Cook et al., 1999). A typical example of the first group of method is provided by the study of Mann et al. (2009) in which the time coefficients of dominant EOF patterns calculated from instrumental climate data, are estimated over the pre-instrumental data using a network of proxy records, and then, the climate field over the pre-instrumental data is attained from the product of the reconstructed time coefficients and the instrumental dominant EOF patterns. The underlying hypothesis is that the primary spatial modes of climate change during the instrumental period also existed in the past and that the order of these principal components have not changed with time. The advantage of this assumption is that only a few proxy records with sparse spatial coverage can be enough to reconstruct a climate field (Neukom et al., 2011). However, the discarded EOF patterns after EOF-truncation may retain some small-scale spatial information, which would have been lost. For instance, the global temperature field reconstruction (Mann et al., 2009) was not consistent with a regional temperature field reconstruction in western Qinling Mountains, China (Yang et al., 2013). In addition, *this method is not well adapted for reconstructions of precipitation field because high spatial heterogeneity of this variable (Gómez-Navarro et al., 2015).*

The PPR-based method (Cook et al., 1999) reconstructs each grid point using a linear regression; e.g., PCR (Cook et al., 1999), RegEM regression (Shi et al., 2015) or the OIE method (Yang et al., 2016) through searching candidate proxy records near the target. The goal of the PPR-based method is to maximize the retention of spatial information, but this method requires a sufficient number of suitable proxy records near the objective grid points.

Item 6: 6. The left EOF patterns may retain some useful regional spatial information, which would have been partially lost in the EOF- based method. For instance, the global temperature field reconstruction using the EOF-based method (Mann et al., 2009) was

The 'left patterns' is unfortunate. It may be misinterpreted as 'left and right vectors' in SVD. I would rather used 'the discarded EOF patterns after EOF-truncation

Response: According to the reviewer's suggestion, these words have been changed with "*the discarded EOF patterns after EOF-truncation*".

Item 7: 7. (Shi et al., 2015a) and the optimal information extraction (OIE) method (Yang et al., 2016). In theory, the PPR-based method maximizes the retention of spatial information, but this method requires a sufficient number of suitable proxy

I also had problems with the description of the OIE method, and also to figure out to what extent this method is different from the PPR method. This manuscript does not give enough details and refers to other previous manuscript by Shi et al. I have quickly looked into those papers and I cannot tell the difference between OIE and PPR. This may be my probable, or the problem in previous manuscripts, but I really would recommend to be much more specific here, and at least indicate the basic difference between OIE and PPR, and what are the advantages, if any, of OIE over PPR in this setting.

Response: Following the reviewer's suggestion, we have rewritten the review of these reconstruction methods to explain the difference between OIE and PPR. In our interpretation, the foundation of the PPR method is that the climate field reconstruction should be obtained through a reconstruction for each grid point. The OIE method belongs to an indirect regression method group, which can be used to reconstruct a climate index or a climate field. The OIE method is based, as for the LOC method, on the principle that the reconstruction process should be based on the fact that the proxy records are functions of climate variables. The main differences between OIE method and other methods are that the correlation coefficients between the local instrumental climate data and the target climate data are used in the computation of the weights in the regression, and the regression coefficients are random variables with normal distribution and vary in the ranges between the classic linear regression and inverse regression to obtain an uncertainty estimation.

Item 8: 8 The precipitation (or the variable sensitive to precipitation) field reconstruction for a large-scale region using the PPR-based method is difficult when only one type of proxy records did not cover all reconstruction areas. For example, the tree-ring

This sentence is too cumbersome. I think I understand what it means, but the authors may consider rephrasing.

Response: The sentence has been revised to "*Selecting only one type of proxy record, with the associated limited spatial distribution, hinders the field reconstruction of precipitation (or of a variable sensitive to precipitation) for a large-scale region using the PPR-based method.*", according to the reviewer's suggestion.

Item 9: 9. regression and inverse regression. The LOC regression method has already been verified to efficiently retain low-frequency climate signals (Christiansen, 2011; Shi et al., 2012).

However, the LOC method has been shown to potentially overestimate the past variability. There is a comment and reply exchange on the Christiansen et al manuscript, and my interpretation of it is that Christian et al. also acknowledge that this could be a problem in certain circumstances.

Response: The sentence has been revised to "*The reconstructions based on the LOC method are assume to better preserve the low-frequency climate signal compared to other method, though they would overestimate the high-frequency signal (Christiansen and Ljungqvist, 2011).*", according to the reviewer's suggestion.

Item 10: 10 2.2 Tree-ring record

Please, be more specific here: three-ring width, isotopes, density, early wood density, etc.

Response: Following the reviewer's suggestion, we will add the data citation for all the proxy records in the revised manuscript.

Item 11: 11 To maximize the overlap lengths of the instrument data and proxy records, all treering records were extrapolated to AD 2000 using the RegEM algorithm (Schneider, 2001). Here, the truncation parameters for the RegEM algorithm were set to

Extrapolation does not include new information and therefore it cannot increase the skill of the reconstructions. Was this step necessary for the OIE algorithm? if not, an explanation is required as to why the records were extrapolated.

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.

Item 12: 12 Discussion section. As I indicated in the preamble, this section actually contains further results, such as the superposed epoch analysis. It also contains the analysis of the link between the reconstructed precipitation and ENSO and the PDO.

As it stands, it is a classical results section. The title' discussion' is misleading.

Response: Following the reviewer's suggestion, we have modified the structure of the paper and combined the results and discussion sections. We use thus the title 'Results and discussion'.

Item 13: 13. The superposed epoch analysis (SEA) between the precipitation, its PC1, and 35 large eruption events during AD 1470-1849 shows that volcanic activity as one important external forcing may affect the MJJAS precipitation anomalies variability for China (Fig. 8). Nevertheless, the signals are barely significant and there are similar averaged scores before and after the

These results are too cryptic. The SEA has not been mentioned before, so the reader is left wondering where this comes from: which eruptions have been included, how were they dated (the reconstructed volcanic forcing of Gao et al and of Crowley and Untermann does not always agree on the dating of the forcing maximum), how was the SEA itself conducted, for instance how many years prior to the eruptions were considered to define the pre-eruption mean, how was the statistical significance established, etc.

Response: Following the reviewer's suggestion, we have added the explanation of SEA method in the method section: "*The superposed epoch analysis (SEA) is traditionally used to analyze the influence of volcanic eruption on the climate, e.g. Bradley (1988). Here, the software to compute SEA has been downloaded from the website (http://blarquez.com/superposed-epoch-analysis-sea/). The period analyzed (time window) are set as 20 years before and after each volcanic eruption event. The three confidence limits (90%, 95%, 99%) are estimated using the bootstrap procedure (Blarquez and Carcaillet, 2010). The eruption time series of Sigl et al. (2015) is used here because of the dating improvement compared to earlier estimates. Four categories of volcanic eruption events during the period from AD 1490 to AD 1829 are chosen following Zhuo et al. (2014)'s method which is based on the magnitude of their sulfate deposition in the Greenland ice-core records: (1) all Northern hemisphere eruption events (CNH0P) according to Sigl et al. (2015), (2) CNH1/2P: the eruption events that have more than half, (3) equal (CNH1P), and (4) double (CNH2P) that of the sulfate deposition of the 1991 Mount Pinatubo eruption. The SEA results for the mean precipitation in China and the spatial patterns are shown in Figure s3*.".

Moreover, we will update Figure 8 as Figure s3 in the revised manuscript using the following Figure 1, which added the spatial patterns of the impact of the Northern Hemisphere volcanic eruption events on the precipitation field for the four categories of eruption (CNH0P, CNH1/2P, CNH1P, and CNH2P) of the volcanic events in Figure 1. *The results show that the signals are barely significant for the mean MJJAS precipitation anomalies variability for China and its PC1, and the spatial patterns between the categories have no consistent variability. This indicates that the response of MJJAS precipitation anomalies for China to Northern Hemispheric volcanic eruption is not robust.*

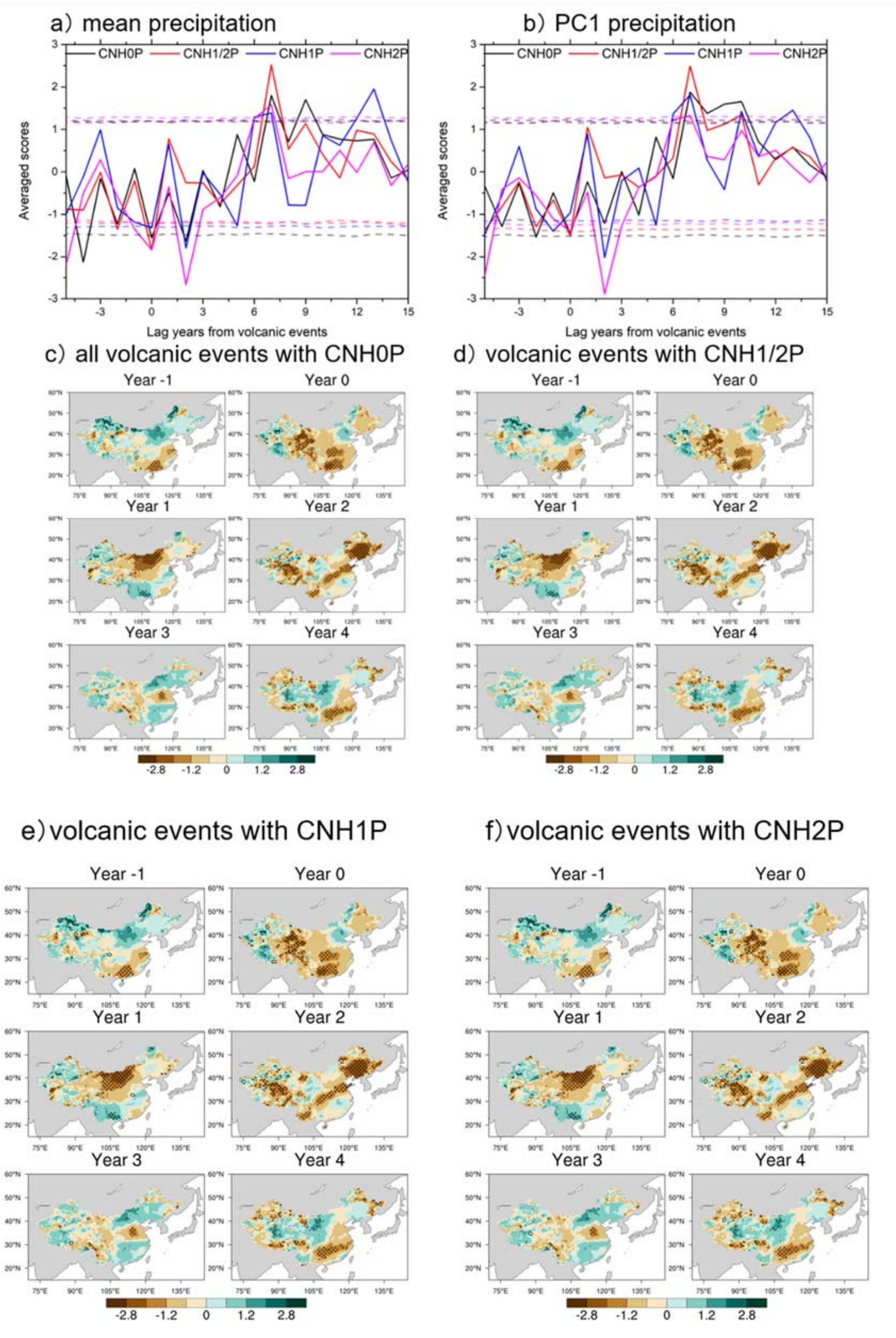

Figure 1 Superposed Epoch Analysis results applied to the mean precipitation anomalies (a), its PC1 (b), and the precipitation field (c-f) response to four categories (CNH0P, CNH1/2P, CNH1P, and CNH2P) of volcanic events as selected in Sigl et al. (2015) with 90% confidence limit during the period AD 1490-1829. The dashed lines

in (a) and (b) are 90% confidence limit. The blank points in (c-f) identify statistically significant grid points at the 90% confidence level. The title of each panel in (c-f) indicates lag year from volcanic events.

Item 14: 14. Our results indicate thus that the south-north mode variability of precipitation anomalies in China carries very likely the fingerprint of ENSO evolution over the past 500 years, but the origin of the EOF1 and EOF3 patterns are not clearly established yet. This implies that the other factors such as North Atlantic Oscillation (NAO) (Wu et al., 2009; Zheng et al., 2016), interdecadal Pacific oscillation (IPO) (Song and Zhou, 2015), North Atlantic triple SST pattern (Ruan and Li, 2016) through the North Atlantic–Eurasia Teleconnection (AEAT) (Li et al., 2013a), the snow cover change of the Tibetan Plateau (Ding et al., 2009; Wu et al., 2012), and changes aerosol concentration (Li et al., 2016) may contribute to the reconstructed precipitation field modes during the pre-industrial period.

This conclusion is rather speculative. Why should EOF1 and EOF3 be related to the large-scale climate? they could be originated by regional processes in China.

Response: We agree with the reviewer's comment. This section is speculative but we wanted to include at this stage the reference to studies potentially useful to explain those patterns. Nevertheless, as we cannot explain the origins of EOF1 and EOF3 at the current stage, the regional processes in China is also a possible factor to affect them. Following the reviewer's suggestion, we have revised the part: "*Our results indicate thus that the south-north mode variability of precipitation anomalies in China carries very likely the fingerprint of ENSO evolution in tropical Pacific over the past 500 years, but the origin of the EOF1 and EOF3 patterns are not clearly established yet. Some studies shown that the additional factors such as the North Atlantic Oscillation (NAO) (Wu et al., 2009;Zheng et al., 2016) and the North Atlantic triple SST pattern (Ruan and Li, 2016) in North Atlantic, the interdecadal Pacific oscillation (IPO) (Song and Zhou, 2015) in North Pacific, the snow cover change of the Tibetan Plateau (Ding et al., 2009;Wu et al., 2012), and some regional processes in China contribute to the variability of precipitation during the instrumental period. Additional studies are then required to determine which of these processes might be related to EOF1 and EOF3 over the pre-industrial period.*".

Item 15: 15. Caption Figure 1. Please indicate what RSQ, RE, CE and uncertainty mean

Response: Following the reviewer's suggestion, we have added the full names of these terms in the caption of Figure 3, like as "*The r^2 is the square of the Pearson product–moment correlation coefficient, the RE and CE are the reduction of error and the coefficient of efficiency, the uncertainty is characterized using the standard deviation of the residual between the reconstructed and instrumental precipitation data during the verification period.*" Moreover, we have added some words to explain these terms in the method section.

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