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Climate of the Past Discussions

Interactive comment on "Development and evaluation of a system of proxy data assimilation for paleoclimate reconstruction" *by* Atsushi Okazaki and Kei Yoshimura

Anonymous Referee #2

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The authors present and analyze a novel approach to directly assimilate proxy information into GCM simulations to reconstruct past climate. They find that while assimilation of isotopic proxies is possible and is clearly beneficial in idealized simulations, the actual benefit of assimilating proxy data is limited due to model errors and the small number of assimilated proxies. Data assimilation in paleoclimatology has attracted a lot of attention recently and the science and methods are developing rapidly. This manuscript represents an important contribution to the field in that for one of the first times, proxy data (rather than reconstructed climatic variables) are assimilated directly for climate reconstructions. Therefore, I recommend this article to be published after the outstanding issues detailed below have been addressed.

General comments:

The sensitivity experiments conducted in this study only 'explain' a small fraction of the difference in correlation between the idealized setup (CTRL) and the application to real proxy data (REAL). The reasons for such a reduction in quality are manifold and include GCM model errors and errors in the proxy forward model that are not quantified in the current analysis. Proxy model errors are shortly discussed at the end of section 4, but it is not clear to me how one could attribute errors to the proxy model or the GCM in the absence of controlled experiments (as also stated by the authors in L504). While performing such controlled experiments with alternative proxy model / GCM combinations is clearly beyond the scope of this paper, I suggest the authors carefully reword the respective paragraphs.

In addition to trying to quantify the limitations of the current proxy DA setup by performing sensitivity experiments, the authors also try to answer a second question: namely whether direct assimilation of proxy data is superior to assimilating climatic variables (here temperature) reconstructed from the proxy data. In contrast to the approach pursued here, it would seem easier to address this question using the REAL experimental setup. Based on this setup, one could derive reconstructed (gridded) temperature data from the exact same proxies that have been used in the REAL experiment and assimilate these reconstructed temperatures instead. Such an experimental framework would be instructive as to whether empirical proxy models (i.e. reconstructed temperatures) outperform the physics-based on-line proxy models. Alternatively, one could devise idealized experiments similar to the ones performed in the study in which one compares assimilations based on the assumption of a perfect proxy model. In contrast to the comparison presented here, one would need to compare the CTRL (or any other of the synthetic proxy experiments) to the corresponding experiment in which the proxy data (+ noise) from the truth run has been used to reconstruct temperatures which are then assimilated. Such analysis, however, may be beyond the scope of this paper and I would be perfectly happy if the authors decide to focus on the main message of

the manuscript – the proxy data assimilation and partial attribution of its limited skill to quantifiable sources – only.

The data assimilation method is not described at all. Please add a short section on the data assimilation method with the relevant references. I suggest to focus on the choices and setup specific to this study and to provide the appropriate references; an in-depth introduction to the data assimilation method would only be needed if you chose a non-standard assimilation method that is not documented elsewhere. If, as suggested by the final paragraph of the manuscript, an EnKF has been used, then I suggest to also analyse the spread to error ratio or compute rank histograms to get an impression whether the analysis spread matches the analysis error and the analysis is well calibrated. Lack of calibration (usually overconfidence) is likely due to a misrepresentation of the observation error matrix (either underestimation of observation error or correlated errors).

Use of the term 'accuracy': The authors repeatedly use the term 'accuracy' to describe the quality of the analysis. This use of language is somewhat misleading, as accuracy in forecast verification has a specific meaning and the appropriate verification score to measure accuracy would be the mean squared or mean absolute error, whereas the correlation is a measure of forecast / analysis association (e.g. Murphy, 1993). I suggest to either rephrase and write of "improved assimilation", "enhanced correlation" etc. or to clearly state that accuracy refers to correlation throughout the manuscript.

Specific comments:

L112: This issue seems important and I think it would be worth revisiting in the conclusions.

L267: stemming from

L363-365/7: Is this a direct quote from the Xu et al. paper? If so I suggest labelling this as such by using quotation marks.

L385: for precipitation

L440: slightly more accurately?

L487ff: if the only difference in simulations is observed vs. simulated SSTs, I suggest the authors refrain from using the term forcing in the following lines for better readability.

L499ff: The discussion of the differences of the various sensitivity experiments is hard to read. I suggest to streamline and reword this section along the lines of "Imperfect SST used to drive the CGCM simulation resulted in a slight reduction of correlation compared to the CTRL experiment with perfect SST."

L513: non-climatic factors.

L514: add reference, e.g. Appendix B of Compo et al. 2011

L525: I suggest to mention that not in all cases direct proxy DA will be beneficial compared to assimilating empirically reconstructed variables. Also, while assimilating more data is expected to increase the quality of the analysis, care has to be taken in assimilating dependent information (e.g. direct assimilation of proxy data and reconstructed variables derived from the same proxy data).

Figure 4: The figure labels denote EOF2 whereas only EOF1 is mentioned in the text. Please fix.

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