

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

Anonymous Referee #1

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Data assimilation in paleoclimatology is a rapidly growing field. The present paper addresses the model-data comparison step that is critical in every data assimilation scheme. Up to now, proxy records are generally first transformed to obtain a reconstruction of simulated variables such as temperature or precipitation before being assimilated. Simulating the measured quantity using proxy system models and performing the comparison directly for this variable provides in theory many advantages. The present study analyses those advantages and the potential limitations of the methodology based on both idealized and realistic experiments. It demonstrates the ability to directly assimilate isotopic composition of several proxies thanks to the application of forward proxy models. The study also identifies the regions/variables where the skill is

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already satisfactory and the promising ways of improvement. The authors thus provide very interesting results for methodological developments and the application of data assimilation techniques in paleoclimatology. The study thus deserves publications in *Climate of the Past* but some modifications are required in the experimental design and in the discussion to reach conclusions that are easier to be interpreted and to be compared with recent work as detailed below.

General Points.

1/ Several groups are currently working on the direct assimilation of proxy records. The authors could not be blamed for not discussing all the very recent publications in the submitted version but a comparison of the conclusions reached here with the ones of Dee et al. (2016) must at least be included as the latter study is focused on a very close subject. In particular, Dee et al. (2016) compare a direct assimilation of isotopes using an isotope enabled atmospheric model with the assimilation of temperature derived from the proxy records, as in the present paper. The publication of those recent papers also requires to modify some sentences like lines 80-81 and 116-117 where it is said that it is the first time that proxy data are assimilated directly (see also Acevedo et al. 2016).

Acevedo W., B. Fallah, S. Reich, and U. Cubasch (2016). Assimilation of Pseudo-Tree-Ring-Width observations into an Atmospheric General Circulation Model. *Clim. Past Discuss.*, doi:10.5194/cp-2016-92, 2016. Available at <http://www.clim-past-discuss.net/cp-2016-92/>

Dee, S.G., N.J. Steiger, J. Emile-Geay, and G.J. Hakim (2016): On the utility of proxy system modeling for estimating climate states over the Common Era. *Journal of Advances in Modeling Earth Systems*. doi:10.1002/2016MS000677. Available at <http://onlinelibrary.wiley.com/doi/10.1002/2016MS000677/pdf>

2/ I was surprised that the data assimilation method was not described at all in section 2.1. If I am right an ensemble Kalman filter is applied but this is only stated in the

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conclusions (the word Kalman is mentioned first line 528). A long description of the method is not required but its main characteristics should at least be mentioned in section 2.1.

3/ The interpretation of experiment T2-ASSIM and its comparison with CTRL are not straightforward to me as the conclusions strongly depend on the signal to noise ratio selected and it is not possible from the information given in the paper to compare this signal to noise ratio with the error used in CTRL. One option would be to use the model results to estimate the impact of an error of 0.5 per mil on the isotopic composition, as imposed in CTRL, on a temperature reconstruction based on those isotopic records using simple statistical methods (for instance a regression as often done in paleoclimate reconstructions). Then, additional sensitivity experiments can be performed with such a temperature reconstruction derived from the isotopic composition (and not using the temperature simulated by the model) or alternatively assimilating temperature using the signal to noise ratio of this reconstruction that would be compatible with the error imposed in CTRL.

4/ The low skill of experiment REAL can have many origins: biases in climate models, limitations of proxy system models, non-climatic noise in the data, local signal in the records not represented in large-scale models, etc. The present study does not address the relative contribution of each of those elements and this is perfectly fine for me as it is not the goal of the present study. Nevertheless, some recommendations like line 51, line 497, line 502, line 506 on the improvement of models seems relatively vague and not really justified by the results. I would thus recommend to be more careful and to focus on the main results of the study.

Specific points

1/ Abstract, line 42-43. This sentence is not clear without reading the main text. Please rephrase (see also general comment 2).

2/ Line 100. The data are not erroneous, this is the interpretation that is questionable.

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3/ Line 143. The 'simplification' is valid for some variables but not for others that change more slowly such as oceanic temperatures.

4/ Line 150-151. What is meant by 'changing the algorithm'. The text should be more explicit and provide a reference if available.

5/ Line 176. A few words should be given on the version of MIROC5 applied as the reference is not available yet. In particular, it should be stated if only the atmospheric component is applied (as suggested lines 214-215) or if it is coupled to an interactive ocean.

6/ Line 189. Why is the deep ocean composition needed for corals that live in shallow waters?

7/ Line 250. I guess the four sensitivity experiments has to be compared to experiment CTRL. This should be already stated at this stage.

8/Line 322. Is it just a repetition of line 318 with a different sign or new information?

9/ Line 333. Why using 'on the other hand' here?

10/ Line 336. The results for temperature should be discussed too.

11/ Line 348. Is this increase noticed in simulation results or in observations? Please be more precise.

12/ Line 411-412. I would suppress this sentence as it does not bring new information.

13/ Line 415-419. I may miss something but I do not see how the low reproducibility of corals could play a role in the perfect model framework of CTRL as it is assumed that the climate and proxy models have no systematic bias (see also line 496).

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