

Review

Manuscript: Joint inversion of proxy system models to reconstruct paleoenvironmental time series of heterogeneous data

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General comments

The authors have generally answered my comments, including implementing a continuous-time model rather than a discrete-time model. In their revisions, there are some new points needing clarification.

Specific comments

1) *Section 2.3 Environmental models*

Now that a continuous time series (cts) model is being used (Eq. 5), it's unclear why the process model is simulated with a "regularly-spaced base series" (paragraph under Eq. 5), rather than just sampling the cts model at the observed (data) time points. Sampling the cts model at only the data time points preserves the uncertainty caused by changes in temporal resolution. (The link between temporal resolution and confidence intervals is mentioned at the end of Section 3.2 in the manuscript.) What is unclear in the manuscript is whether Δt (in Eq. 5) is:

- a) $t_i - t_{\text{last regularly spaced point}}$, OR
- b) $t_i - t_{i-1}$ i.e. the time difference between the observed time points.

If $a < b$ then the variance of the smoother may be artificially smaller.

Also a reference to a statistical text that provides the background theory about continuous time correlated random walk models (i.e. the origins of Eq. 5) should be included.

2) *Section 2.4 Model inversion*

"we conducted three different analyses, the first two inverting data from each site independently and third inverting both records together". Although the authors have given a better description of the latter (in their subsequent sentences), the "why" remains unclear. Is there any expectation here that inverting both records together should for some reason be different than inverting both records independently? Explain why or why not.

Technical corrections

(page and Line numbers refer to the clean revised manuscript)

Fig. 1: In Figure 1b and caption, the symbol ε is used, whereas ϵ is used in the manuscript text. Please clarify.

p5 L22 “ t_{swp} and σ_{swp} are the estimated age and uncertainty” is still ambiguous. Please add an adjective before “uncertainty”, because σ_{swp} is not age uncertainty (and that’s how it reads).

p9 L23 “original authors” I’d clarify this by saying “Both reconstructions are similar in nature to the reconstructions provided by ...” and cite the papers.

p10 L7 “values of these parameters” change to “values of these variables”. I think the word “parameter” should be reserved e.g. for the coefficients of a statistical model.

p10 Heading 3.2 “Time series properties” vs 3.3 “Model properties” In the opening paragraph of these sections, please give a definition of “time series property” and “model property”.

p12 L32-L34 The median value of the autocorrelation (~ 0.9) is given for site 806, but please give the median value of the autocorrelation value (in brackets) whenever you qualitatively state “strongest autocorrelation” or “much lower posterior” in this paragraph. Also, the autocorrelation posterior density (Fig. 7d, solid line) for BWT seems to suggest a weak autocorrelation, which doesn’t match the sentence on p13 L1 “the data strongly support highly coherent high-amplitude cyclic variation in BWT”. Given such a pattern, I would have expected a higher autocorrelation.

p13 L9: “providing ... supporting” or “provide ... (thus) supporting”.

p13 L13 “ad hoc methodological choices” Just a comment. But there are other issues with dynamic linear models, including choice of the components of the process model, and the lack of model cross-validation.

p13 L17 How much is a “slightly higher probability of a significant change”? (include numerical values in brackets). Is the probability of *no* change from Modern higher or lower at 0 Ma for which method?

Fig. 8a caption “Site 806” not “809”

Fig. 8b The red line is not referred to in the 8b caption (one can guess that it corresponds to the left y-axis).

Is the phrase “all other symbols as in Fig. 2” necessary?