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Climate of the Past Discussions

Interactive comment on "Technical Note: Correcting for signal attenuation from noise: sharpening the focus on past climate" *by* C. M. Ammann et al.

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We are very appreciative of the detailed comments on our technical note provided by a total of six referees. The impact of their constructive suggestions will be noticed in the three areas of common focus across the reviews: (1) Improved clarity of the description of the estimation procedure for the unknown variance of the noise, (2) a broader referencing of literature than the narrow focus we intended initially for his technical note, and (3) the further assessment of robustness of the proposed method through inclusion of additional, and memory carrying noise applied to the samples to represent more realistic reconstruction conditions. Because there was substantial overlap in the

comments across the reviews (some explicitly recognize that), we provide here a broad summary of these key points first, and then keep the direct replies to points made by individual reviewers brief.

An upfront note to keep in mind when evaluating some revisions provided in the main text as well as the Supplementary Material: This contribution is a "Technical Note" in which we tried to provide a simple description and explanation of the cause of a fundamental problem in regression-based reconstructions that arises from noise in the predictors. Our intent was then to provide an example of how the method works and illustrate its properties through comparison with one simple regression method as a stand-in for the general issues. Neither the actual application, nor the calibration vs verification conditions existing in the real world were of particular concern because the Technical Note is merely an introduction. Its limited space does not provide the opportunity to test the method thoroughly under all possible real-world conditions. However, we do see a point in the suggested limited expansion that reviewers regarded as necessary. We have added simulations with additional noise (both white and red); yet at the same time clearly recognize that these brief tests cannot replace an in-depth, comprehensive evaluation. These need to be done elsewhere, and we invite the community to join in this effort.

We hope that we have answered the questions that relate to the description of the method and the broader context within the existing literature. Additionally, we have expanded on noise-examples that were requested.

Primary points of concern by (essentially) all of reviewers:

Clarity of estimation procedure for residual variance : The reviewers correctly recognize that estimating the variance of the noise U is the critical step in our method. As requested, we have expanded the explanation of how a cross-validation step is used to find the minimum bias in the reconstruction of a withheld segment and qualified the statement by acknowledging that other approaches might exist to achieve the same result. The choice would depend on the data and noise issue at hand. A brief explanation how parameter k is estimated using cross-validation is given in a new first section in supplementary Material. Related to this issue, and only brought up by a couple reviewers is the issue of verification / validation. In real-world application such validation steps are often added to provide measures of confidence in the reconstruction. Here, the focus was on demonstrating the efficiency of the method while the true result is known. Other than the visually clear results, we don't discuss this separate problem in the main text. The issues about verification are independent of the reconstruction method. However, we have included a paragraph with a short discussion in the Supplementary Material and believe that we cover the sentiment indicated by the reviewers. We also reference various discussions in the literature about this very issue that provide further pointers for the reader.

Literature on both broader use of measurement error issues as well as paleoclimate context. We highly appreciate the reviewers' constructive suggestions for references. We are glad to see that there is some awareness of the issues already in the paleo community. This strengthens our confidence that our contribution can have a positive impact and might find interest. As requested, we have broadened our referencing across the board rather than keeping also the reference list as short as possible. There is clear benefit in this, the reviewers are absolutely correct, though we hope the journal can accommodate the number. It is worth mentioning here that we did not reference one particular branch of the literature because we are on record (in publications) for disagreeing with several implementations and conclusions. But given the reviews we decided to provide the full exchanges for the readers. Again, the initial intent was to keep the details as brief as possible for a Technical Note, but recognize that the broader impact benefitted by expanding. We appreciate the insistence of the reviews.

Idealized noise structure in proxy example. The reviewers criticized our overly "idealistic", and in fact "perfect proxy", example. While they are correct that the proxies used for Figure 2 were direct "perfect" samples from a climate model, one needs to recog-

nize that twelve points taken from a grid with $\sim$3600 points does not really present a very "idealistic" exercise. Would we have taken >100 samples as is sometimes used in the literature (the examples the reviewers were referring to), clearly then the reconstruction problem would be different and we would certainly agree with the reviewers. However, using just 12 points for a Northern Hemisphere mean are never considered in "perfect proxy" exercises based on GCM output in the literature. As an argument that the example is not that far away from an actual real world case, we mention in the text that the relationships of the 12 samples to the true (known) NH mean temperature of the model were found to actually be quite comparable to the reconstruction by Hegerl et al. (2006/2007). We still believe that the illustration of the difference between a straightforward Ordinary Least Squares approach and our ACOLS solution is quite striking and drives home the point about attenuation of the signal by noisy predictors.

However, we happily heed to the requests of showing brief examples where "white" as well as "red"-noise were added to the predictors in our reconstruction example. The benefit of ACOLS remains, as expected, yet the improvement for the manuscript is also a more nuanced discussion of how the inflation of variance is distributed in time. Certainly with red-noise present in predictors, the noise and thus the variance in the reconstruction ensemble range gets spread out, just as predicated by several reviewers. We believe that this expanded discussion is indeed beneficial for the paper.

Brief replies to individual requests or criticisms in the reviews:

Ref #5 (Anonymous #3) Issue of "perfect proxy": see above. This issue is much less severe than the reviewer indicates. We have done the additional simulations for Figure 2. For figure 1 we did not repeat this exercise because the result can be read out of our red-noise example with grid-samples. We keep Figure 1 as clean and simple to understand. The red-noise example is more "applicable" under a real climate problem. Further the surprise for the reviewer that OLS did not behave better is due to the fact that only 12 points were used. This is very different to exercises where >100 samples are taken in the literature (see above).

This reviewer also points out the problems of estimating the residual variance properly. We discuss above how we chose our procedure.

Referencing the broader literature, including the trace within paleoclimatology: We have expanded on the references (see discussion above). The specific example about Mann and Rutherford publications not being good representations for attempts to minimize variance loss is actually not quite correct, and we don't' see that our referencing these studies is a mischaracterization. The TLS results (together with the split frequency calibration) did target the amplitude preservation. What was key in these publications was that the underlying data did not contain much more variance! In fact, the coldest proxy conditions occurred around 1900, which is essentially covered by the calibration period. The original method of Mann et al. (1998) however has been found to be potentially biased (lost amplitude) if applied to different data such as GCM data (Ammann and Wahl, 2009). The TLS method later used, however, and thus mentioned as appropriate references, did not substantially suffer from this potential. Therefore, we retain these references. But as the reviewer requests, we also include newer literature more extensively. This should satisfy the reviewer's request for a more broad grounding of the argument in the literature. Other examples given by publications using Borehole data or Mobergs selection of specific low-frequency records are not to the point at hand. The question with ACOLS is if one can better reconstruct the low-frequency signal (mean amplitude) GIVEN data. It is undisputed that should the proxy data not contain low-frequency signals, then even a perfect method could not retain it. Literature: expanded referencing, including most of the requested ones.

Specific comments: 1) Estimating of k through cross-validation: Done, see above and Supp. Mat. 2) "What does insensitive to values around this choice mean": we provide a more explicit range in the text. Done. 3) Variance enhancement concentrated at interannual scale: We have now qualified this statement and if red-noise proxies are used, then the variance inflation will be drawn out to lower frequencies as well. However, we do point out that in contrast to other reconstruction methods, ACOLS does perform

very well on interannual scale as well (see Figure S1!). So depending what question is asked, one can comfortably average results to decadal means and talk about climate issues, or retain full annual resolution and look at variability. ACOLS provides both. 4) "Watchful eye on variance": This expression simply indicates that if very noisy proxies, and particularly if red-noise proxies are used, then the year to year – or even decadal – variance can be substantially larger than true climate variability at that time scale. What our method provides is a robust measure of the mean.

We think we have significantly improved how our text fits into the literature context, provided that one recognizes that this is a technical note to introduce this method in this literature. A full intercomparison is not possible within this framework.

Interactive comment on Clim. Past Discuss., 5, 1645, 2009.