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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 ∼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 #4 (Brohan) He brings up the worry that real world proxy would behave differently than the shown example. We include now white and red-noise examples incl. discussion of the changes in performance that are much closer to real-world conditions (see above), again within the limits available in a Technical Note.

Brohan brings up a "worst" case scenario for paleoclimate reconstructions: Non-linear, or non-stationary climate representation by proxy records. Similar to the discussion of possible various noise-models, we cannot deal with such issues in this Technical Note.

Non-stationarity, very likely cannot be dealt with by any method.

Minor Points: 1) New discovery... No, we do not claim this to be a new discovery. Everywhere do we refer to, and even explicitly state, previous literature in the field of statistics. See also abstract. We also point out the broad literature in Astronomy that touches on measurement error. Our goal, and thus the chosen example, is to provide a simple and concise introduction of the method for paleoclimate purposes. We have improved the referencing (see above) and cover this point quite explicitly. 2) Description of estimation of residual variance (see above) 3) Comparison with other methods: See above. However, Brohan mentions that TLS is not particularly difficult to implement, and estimating two variances is essentially the same as our estimate of sigma_U: We believe that this is not quite the case and actually provide solid literature references by experts in that field of measurement error. Estimating a ratio of variances is inherently volatile. Small errors can have large effects. We point this out by showing the end members of TLS solutions in Figure 1. We do mention that some applications quite likely have this potential error quite small because they could use model data to estimate. But what should be done when noise in observations and in proxies are both unknown? The volatility of the ratio is what led us to ACOLS. 4) Increased variance is actually across all time scales and not concentrated on small scales: We believe that increased variance has different effects. While the full reconstruction is indeed inflated by an increased regression slope, the low-frequency signal is now accurate while the high-frequency signal is potentially quite noisy. By minimizing the bias, we fix the low-frequency problem. In standard OLS, the high-frequency would be quite accurate, but the low-frequency (larger amplitudes) would be off (see bias, and also Fig. S4 in Supplementary Material). Therefore, the selection of procedure will depend strongly on the question at hand.

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