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Climate of the Past Discussions

Interactive comment on "Optimizing sampling strategies in high-resolution paleoclimate records" *by* Niels de Winter et al.

Anonymous Referee #1

Received and published: 24 November 2020

In 'Optimizing sampling strategies in high-resolution paleoclimate records', de Winter et al. propose four data treatment methods for constraining (paleo)climatological parameters from sequentially-sampled isotopic records and interrogate the accuracy and precision of each of these approaches using a combination of real and virtual datasets. Seasonally-resolved proxy data (e.g., δ18O and more recently Δ47) offer the potential to provide greater clarity into past climates. However, a number of factors complicate the interpretation of these archives. Conventional oxygen isotope thermometry requires an assumption regarding the isotopic composition of seawater, which, as the authors point out, is both spatially and seasonally variable even in the modern ocean. Clumped isotope thermometry is independent of seawater composition, circumventing this limitation, but comes with a much larger analytical uncertainty (made even larger

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by the small sample sizes required for sub-annual resolution) and thus the data can be noisy. By exploring how these and several other factors, such as sampling size and length of record, impact the accuracy and precision of recovered climatological information, the authors are able to develop a framework for determining the best sampling and statistical strategies to maximize the fidelity and minimize the uncertainty of these recovered parameters.

This study serves to significantly advance sclerochronologic research by providing critical insights into the uncertainties surrounding seasonal analyses and a quantitative, statistically-rooted means of extracting useful climate information from often noisy records. Overall, the paper is well-written, the experimental design well thought out, and the discussion thorough. The topic is pertinent and will be of interest to a broad paleoclimatological audience. I recommend only minor revisions, most of which pertain to improving the clarity and readability of the manuscript.

General comments:

(1) Based on Figs. 6, 7, and 12 it seems like the δ18O reconstructions aren't necessarily less accurate than the other approaches, but that the accuracy of the results are more variable. The approach accurately reconstructs MAT in Cases 1-14 and 19-29 and accurately reconstructs seasonal range in Cases 1-6, 19-24, and 30-33. Significant deviations occur only when the mean annual δ18Osw differs significantly from the assumed value and/or when there is a strong seasonality to δ18Osw (which, as you point out, is a realistic and often ignored scenario).

Given these findings, I'm curious why you have not attempted to combine the δ18O approach with another method to maximize both precision and accuracy of the results. If, for example, you were to use the binning or optimization of clumped isotope technique to constrain the seasonal seawater cycle, you could then apply those results to the higher-precision δ18O approach and alleviate the assumption of normal-marine/invariant seawater composition. For a real-world example of this approach see

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Keating-Bitonti et al. (2011), who use bulk summer and winter clumped samples to identify a summertime freshwater influx impacting their oxygen isotope values.

(2) Though beyond the scope of the variables considered here, there are two additional complicating factors in real-world sclerochronologic data that may be worth mentioning at some point: (2a) Unequal sample time-averaging as a function of growth rate - in practical application (versus virtual subsampling), the number of days (or weeks or months) averaged into a single sample will vary; when the organism is growing quickly the sample will represent comparatively less time than when it is growing slowly, using the same diameter drill bit. If growth slowdowns/hiatuses, e.g., correspond with winter extremes, this results in not only fewer but also more time averaged (and thus dampened) estimates of winter temperature. (2b) Uncertainty in the seasonal phasing of SSTs in paleoclimate studies – even in instances were samples from a fossil specimen can be aligned along some reliable age model (be it via growth band counting or a statistical model), assigning those data points a calendar date is ambiguous at best. The timing of the date of maximum and minimum SST can vary considerably based on latitude, environment, and other local factors. This is a particularly important source of uncertainty to consider when binning the data by month – shifting the calendar date assumptions by, e.g., 15 days, would result in a whole new grouping of monthly data points and could significantly alter the results.

(3) Regarding the figures, I really appreciate the consistent color theme throughout, but for accessibility purposes you may want to double check that the color scheme is colorblind safe. Additionally, there is a lot of really useful information that is not always easily extracted from the figures – I'd encourage you to think about creative ways of graphically presenting the information that will allow the reader to quickly glean the most important aspects. For example, you could include a heatmap showing how accuracy and precision vary by case and climatological parameters (similar to the colored conditional formatting of S12), which may be easier to interpret than the line plots.

(4) I'm not convinced that Section 5.4 (Implications for other sample size problems)

sufficiently contributes to the overall content of the manuscript to warrant inclusion. This section reads like a grant proposal rather than a discussion and could easily be condensed into a single one-paragraph section briefly outlining potential additional applications of the approach.

(5) Prior to the final submission, the manuscript, supplement, and figures all require a thorough read through to ensure consistency of terminology, case numbers, and color scheme. For example, high precision/accuracy are at times conflated with high reproducibility error/offset in the text. Case numbers are not always consistent (both in the text and supplements), and it appears as if the colors have been switched in at least one figure. I've tried to point out examples of these in the line-by-line comments, but I'm sure that I've missed some. The supplemental files are hard to navigate - it would be helpful to include a 'Read Me' tab in applicable excel files defining all acronyms and abbreviations and descriptions of the information provided in each subsequent tab.

Specific Comments.

*NOTE: line numbers restart after L347; second set of line numbers indicated by LN

Text:

L12: The term 'events' is a bit ambiguous here, particularly since the manuscript focuses on recovering climatological parameters (i.e., multi-year averages that smooth 'events')

L54: 'the seasonal cycle is the most important cycle in Earth's climate.' This is a bold and rather subjective statement – I can think of many who might argue the carbon cycle is equally important. I'd suggest changing 'most' to 'one of the most' or omitting the statement all together.

L91: Colon missing after 'Optimization'

L120: Consider changing 'depth domain' to 'sampling domain' (here and in all subsequent references); ontogenetic trajectories aren't necessarily depths

L121: Delete ‘this’

L139: There’s an error in this equation (δ18Osw,freshwater is repeated twice). The mass balance should read: δ18Osw = f* δ18Osw,freshwater + (1-f)*δ18Osw,ocean

L142: Space between the per mille symbol and VSMOW; this information is repeated on L145

L157: Change ‘is’ to ‘are’

L159, etc.: I’d suggest stating upfront that all references to seawater composition are in reference to VSMOW; the VSMOW reference after each composition is a bit clunky

L217: Should be case 31 not 30, I believe

L272: Was the seasonal seawater composition range calculated based on the difference between warmest and coldest month (as described in the text) or between the most depleted and enriched δ18Osw seawater months? There are many examples where the SST and seawater cycles are out of phase (e.g., springtime snow melt flux driving a δ18Oseawater depletion extreme prior to the summer temperature extreme). The difference between peak summer and winter seawater composition is an important variable to constrain, but it does not necessarily always equate to the seasonal range in δ18Osw.

L285: Is it fair to assume a normal marine in this environment? I suspect that this was done to illustrate a point and while I don’t disagree that constraining mean annual (let alone seasonal variability) in δ18Osw in deep time adds huge uncertainty to conventional oxygen isotope interpretations, we can often make somewhat more realistic estimates of the (mean annual) value based on latitude and environment than just the global normal marine value.

L294: Lower accuracy or higher offset

L294: Change ‘on’ to ‘of’

LN14: Accuracy improves, offset decrease

LN14: Change ‘samples year’ to ‘samples/year’

LN128: Add a space between ‘and’ and ‘Tagliavento’

LN136: Higher precision or lower reproducible error

LN163: I’m unclear how ‘event or spike’ relate to the examples discussed here; I suggest omitting for clarity.

LN194: Change ‘as’ to ‘at’

LN231: Modify ‘case of exceptions, in which’ to ‘cases in which’ for clarity

LN248: Change ‘Cases 26’ to ‘Cases 2-6’

LN380,382: Are the double hyphens (between 14–24 and 14–18) intentional?

LN456: ‘between 210 ppm’ is not a range, I think a hyphen or a second number is missing

Figures:

Figure 2: Consider adding heading labels for the blocks of virtual cases (e.g., a ‘Sensitivity cases’ header for 1-13, ‘Natural cases’ for 14-18, etc.). It will help focus the reader’s eye to the differences between cases and will serve as a more useful reference throughout the results and discussion.

Figure 7: Color scheme is off in this figure – it looks like the smoothing and binning data may be reversed in the box plots.

Figure 9: Please define RSD in the caption (the definition is there, but it is never directly linked to the acronym)

Supplement:

S12: Case 18 is missing (Natural case 5); numbering of all subsequent cases is off

References cited:

Keating-Bitonti, C.R., Ivany, L.C., Affek, H.P., Douglas, P. and Samson, S.D., 2011. Warm, not super-hot, temperatures in the early Eocene subtropics. Geology, 39(8), pp.771-774.

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