

Geochronology Discuss., author comment AC1
<https://doi.org/10.5194/gchron-2021-15-AC1>, 2021
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Reply to RC1

Stephanie Harmonie Arcusa et al.

Author comment on "A Bayesian approach to integrating radiometric dating and varve measurements in intermittently indistinct sediment" by Stephanie Harmonie Arcusa et al., Geochronology Discuss., <https://doi.org/10.5194/gchron-2021-15-AC1>, 2021

We thank Reviewer 1 for their comments, and we agree the suggestions will improve the quality of the manuscript. We note specifically the Reviewer's understanding that the value of our proposed approach rests on the potential it brings to produce a chronology from indistinct or incomplete sequences, whether lacustrine or otherwise. We argue that more sites are likely to have indistinct or incomplete sequences than not, and every effort should be made to extract information from those, regardless of their quality, especially if as we propose, the quality can be fully assessed. Further, we agree that the manuscript is too long. Our original idea was that the supplemental data (e.g., grain size, LOI, XRF ...) was important to understand the chronological record, and why it may be incomplete or indistinct. However, the inclusion of that material does increase the complexity of the manuscript and as commented, the writing did not transmit this complex information clearly. Thus, a revised manuscript will remove the supplemental data and focus on demonstrating the use of the Bayesian model more specifically.

General comments

The manuscript by Arcusa et al. presents an important new approach to construct and improve chronologies based on the varved sediments. While it is applied to lake sediments, by principle it can be used also for other settings where dating is based on the annual increments of the material. This manuscript is a substantial development of the Bayesian approach, effectively combining strengths of the radiometric approaches and varve-based calendar age scales. Authors accurately identified sources of errors in the varve chronologies construction and aimed to minimize their influence by employing Bayesian methods. Generally, I agree with the discussion, as it is rather technical and brief in the interpretation of the environmental processes. In my opinion, manuscript is suitable for "Geochronology" journal and will gain wide interest, paving way for more accurate, reliable, and unified varve chronologies. However, there are some issues that need to be addressed prior to publication. This is especially length of the manuscript, which at times loses focus.

Specific comments:

Comment 1: I suggest that the Authors reconsider the title. Given that the manuscript shows a promise for more general remarks it should be the focal point of the title. It looks

like a great tool for sediment profiles with missing varves, but for entirely varved sequences it can be even better. There are strong points in the paper: R package, Bayesian varve-chronology model, integration with radiometric dates and so on.

--> *We agree with the suggestion to change the title. A revised manuscript will focus less on understanding Columbine Lake and more on demonstrating the potential of our geochronological approach. The revised manuscript's title will reflect that change.*

Comment 2: This paper is introducing a new methodological concept, yet it lacks clearly resolved suggestions at the end (think Fig. 3 but even more general), and outlook. Generally speaking – which codebase and repository should be used in the future? One model integrates Gibbs sampler, the other does not and so on, is it going to be merged? By the end of the paper, there may be some expectations from the potential readers, that are not met at this point.

--> *We note the need for a more clearly defined tool. The VarveR code is available as an R package. The Gibbs sampler code is currently only available through Github and Zenodo. Merging the Gibbs sampler code into the VarveR model code will be our preferred outcome but will be a significant undertaking. Because of the scale of the efforts required to do so, we suggest that the revised manuscript will present the Gibbs sampler code as an example of how this method is implemented and will include text to clarify that developing the code into a user-friendly package will be a future undertaking. The revised manuscript will also make clear that the authors are willing to work with potential users to adapt the code to their specific situation.*

Comment 3: Integration of the geochemical data. It is interesting and useful to describe sediments, varve types and their formation (it is used to cluster the data, for example) and overall paleoenvironmental conditions. Yet, in my opinion, especially given the Introduction there is no clear indication for the geochemical data importance, it was unexpected addition. Because of that, manuscript seems to trail a little bit out of focus and is discussed with details that are not necessarily important. It is only at the end of the paper that the geochemical data is brought to the attention. There it is partially justified but it lacks in the context of the chronology development, even though it provides insights into the factors influencing the varve quality.

--> *Our original idea was that the supplemental data (e.g., grain size, LOI, XRF ...) was important to understand the quality of the chronological record, and why it may be incomplete or indistinct. However, we agree that the importance of their inclusion is not made clear in the text. We will revise the manuscript to not include this supplemental data. The revised manuscript will only keep the varve quality code, varve type, and varve thickness. The revised manuscript will not include grain size, BSi, magnetic susceptibility, or XRF, nor the associated dendrograms and biplots. We agree that removing this content will help focus the manuscript, improve the clarity of the story, and shorten the text.*

Comment 4: Authors suggest that missing lamina can be a result of erosion. Is there any evidence that over the history changing productivity and mixing could have changed formation and preservation of varves more than erosion? (5.1.1)

--> *Yes. The geochemical data suggest changing productivity and likely some changing mixing regimes, most clearly seen in the topmost and bottom most sections, respectively. It is possible that in addition to erosion, more minor changes in productivity and mixing could have impacted the formation and preservation in the middle sections. The revised manuscript will address this point more clearly in the discussion.*

Comment 5: Do the Authors see possibility to expand the model with, for example, results from varve counting on geochemical and geophysical maps/profiles, which sometimes

show better rhythm and separation of varves. If so, how varve quality codes would be associated with that kind of data?

--> *The model uses ArcGIS shapefiles of lengths between couplets as drawn from an image. The calibration to the appropriate units occurs in a second step. Theoretically, the lengths could be as easily drawn from geochemical data or geophysical profiles if the result is an ArcGIS shapefile. The varve quality codes would be more problematic, but can be turned off, or set to a uniform code of the user's choosing. The revised manuscript will comment on this broader application and how to make it possible to use our approach for other sites and types of sites.*

Comment 6: Do the Authors see possibility to employ at least some of the proposed advantages to one-core sites? If so, then include it in the text. Multi-core research is often cost and time consuming, and not always possible.

--> *We agree that investigating multiple cores is time consuming, more costly, and not always possible. We were fortunate to be able to design our sample collection to include multiple cores after gaining knowledge from an initial sampling campaign that the Columbine sediment was laminated but indistinct and incomplete. Our presented approach builds on the main assumption that multiple cores can be used to inform on the missing sections in ways that a single core may not be able to. As is demonstrated in the manuscript, it is possible to use multiple observers on the same core, and with some changes to the code, it would be possible to use the model on single-core. Although possible, this approach is unlikely to encompass the full uncertainty arising from variations in the sediment because the multiple observers still represent one location, and not multiple, as the multiple core approach would. Nevertheless, this single core, multiple observers is still preferable to a single core, single observer/count situation. Additionally, after some code modification it would also be possible to use a multi-measurement approach, by combining for example, varve delineations from images and geochemical data. This would provide another estimate of uncertainty. The revised manuscript will comment on these possibilities.*

Comment 7: I think that for the discussion of the rationale, there should be reference to VARDA database (Ramisch et al., 2020; <https://doi.org/10.5194/essd-12-2311-2020>) – an attempt to standardize varve chronologies with Bayesian modeling – it shows that it is an important issue worldwide.

--> *The VARDA database is clearly an important project, highly relevant to this work and will be added to the revised manuscript.*

Abstract:

L10-11: weather alternative archives are available or not varves still provide superior archives.

--> *Agreed, and we argue that even varve archives with indistinct/intermediate varves are still highly valuable.*

L11: chronology goes before paleoenvironment.

--> *This will be changed in the revised manuscript.*

L15: "sediments", thin sections are just mean to preserve and investigate the material.

--> *The reference to thin sections was included to distinguish from other possible means of preserving the material. As the revised manuscript will focus more on the broad*

application of the approach, we will revise this too.

Introduction:

L35: maybe: due to time, density, and supply – however please consider that density itself is affected by time (compaction, post-depositional processes) so I'm not sure about putting it on the same line as time and source. In general, fluxes seem to be better but once there is a drastic change in sediment accumulation rate most of the constituents will likely follow. So relative representation is also useful.

--> We agree that relative representation is also useful, especially as the impacts of time, density and supply will still affect fluxes. The revised manuscript will moderate the current statement that "flux is more meaningful".

L68-9: I'm not sure if parenthesis information adds to the introduction.

--> We will remove those in the revised manuscript.

L73-4: "For example" at the beginning of the sentence and at the end.

--> This will be removed in the revised manuscript.

L75: reveal intervals where missing varves can be inserted.

--> This will be changed in the revised manuscript.

L80: I'm missing a link between these two paragraphs.

--> The revised manuscript will revisit the text to improve on this transition.

Last paragraph: Consider changing the order, first introduce rationale – there are few robust, long chronologies in the area and so on, therefore Columbine provides somewhat unique research material.

--> We agree with the reviewer and will make the corresponding change.

Study site:

L89/103: It' a matter of preference but maybe add m.a.s.l.

--> We agree with the reviewer and will make the corresponding change.

L91: formation and preservation...

--> We agree with the reviewer and will make the corresponding change.

L103: rephrase maybe so climate is not typified by the climate itself.

--> We agree with the reviewer and will make the corresponding change.

Methods:

L114: Probably UWITEC, without "H".

--> We agree with the reviewer and will make the corresponding change.

L117: "Error! Reference source not found".

--> *The revised manuscript will fix this.*

L118: shallower depth meaning? Please put coring depth close to the respective core codes in L114. It's interesting to see what the change in depth was making that much difference in varve preservation.

--> *The actual depth will be added to the text, but the difference is on the order of tens of centimeters. We hypothesize that core COL17-1 was collected from the slope out of deeper pocket with the difference clearly enough to allow or not the preservation of the laminations.*

L121: analyzed with non-destructive rather than for.

--> *We agree with the reviewer and will make the corresponding change.*

L128: minimum peak of what? Minimum reflectance peak/Rmean?

--> *Minimum reflectance peak.*

L134: what was the treatment?

--> *A brief sentence will be added to summarize the treatment (H₂O₂ and water bath).*

L135: you provided details for previous methods, what was the equipment used here?

--> *The equipment model number will be added into the revised manuscript.*

L148/155: reference to the papers is fine, but maybe consider adding package versions of rbacon, rplum and SERAC?

--> *Those will be added, especially in the references.*

L150: line is redundant: statistical framework that uses statistical inference.

--> *This will be removed in the revised manuscript.*

L151: why do you mention CRS particularly in this place?

--> *This was mentioned because Plum was specifically tested against CRS and not CFCS in its development. The reference to CRS will be removed in the revised manuscript.*

L165: calibrated for/to what?

--> *The microscope is connected to a measuring software, that is calibrated against a factory prescribed ruler so distances can be converted from pixels to SI units. The revised manuscript will change the text to reflect what is meant by calibrated.*

L175: what R version? There are important changes between the big versions like 3, 4 or 4.1.

--> *The revised manuscript will identify which R version.*

L181: curious: why FactoMineR rather than base PCA?

--> *Simply because FactoMineR had prettier biplots that could be implemented in an easier fashion! The revised manuscript will not include the biplot so the text would be amended.*

L194: principle is general, so sections rather than thin sections.

--> *We agree with the reviewer and will make the corresponding change.*

L196: do you consider developing approach based on other file system, rather than proprietary shapefiles?

--> *Developing the approach without the need for the proprietary shapefiles would be the ideal goal. However, developing the approach based on open-source file systems would be a considerable effort. We suggest keeping this improvement for a later upgrade.*

L196-7: what is necessary to record: depth and code/name of layer?

--> *All three inputs ((1) thicknesses for each varve for each core, (2) site-specific marker layers to stitch the thin sections together into a varved sequence, and (3) inter-site marker layers) are necessary for the code to work. This will be clarified in the revised manuscript.*

L215: if you introduce the paragraph properly, I see no need for 220-227 to be discussed after the code 6. It can and should be discussed immediately after 4. Especially that you introduce idea of simulation as code 6 was "similarly" emulated, but it is presented afterwards.

--> *This is noted and will be changed in the revised manuscript.*

Paragraph starting at L229 needs to be more concise.

--> *This is noted and will be changed in the revised manuscript.*

L245: there is already subject in the sentence, no need for Columbine Lake at the end.

--> *This is noted and will be changed in the revised manuscript.*

L248: and expert judgment.

--> *This is noted and will be changed in the revised manuscript.*

Paragraph at L255: rewrite to avoid redundancy from previous sections in Methods and try to be more concise. L260 no need for parenthesis.

--> *This is noted and will be changed in the revised manuscript.*

3.8 and 3.9 can be as well one section. This subdivision seems unnecessary. Avoid redundancies.

--> *This is noted and will also be changed in the revised manuscript.*

L272: that kind of detail on algorithm etc. could go into the code comments or other kind of supplementary materials.

--> *Detailed code commenting will be moved to the supplementary materials to help with readability.*

L277: if by adjusting – typo?

--> Yes, "if" will be removed.

Results:

L303: I don't think that "redox" should be used as an adjective for any element (Mn). Its state is controlled/sensitive to redox changes.

--> *This is noted but will be removed from the revised manuscript when the geochemical data is removed.*

L313: in the microfacies analysis...

--> *This is noted and will be changed in the revised manuscript.*

Section 4.2 Please indicate that further in the text you are using "lithozones" to describe seasonal/event layers and structures within the varves. Also, first and second sentence can be shortened and merged into one.

--> *This is noted and will also be changed in the revised manuscript.*

L353: space missing in <5 (or remove space in previous notations).

--> *We agree with the reviewer and will make the corresponding change.*

L356: deeper. Try to be more concise.

--> *We agree with the reviewer and will make the corresponding change.*

L410: while I get that Bayesian model must produce confidence interval, the density region starting at 1679 CE seems to be strange by the definition if it is on the depth where unsupported Pb just vanished.

--> *That is well noted, and we would need to change our code to include constraints on the confidence intervals which may be challenging. In the revised manuscript, we will include text to highlight this flaw.*

L415-420: maybe move some of the details to Methods and avoid repetition.

--> *This is noted and will be changed in the revised manuscript.*

L450: space missing in <100 (or remove space in previous notations).

--> *We agree with the reviewer and will make the corresponding change.*

L4620: missing "l" in model.

--> *We agree with the reviewer and will make the corresponding change.*

Discussion:

L501: First part of the sentence and subjects are in mismatch. Chronologies versus profiles.

--> *This is noted and will be changed in the revised manuscript.*

L507: structures of the...

--> *We agree with the reviewer and will make the corresponding change.*

L540: this is rather typical. Often these splits will occur on the unconformity between the layers of different density and properties.

--> *The manuscript comments on this problem to highlight that the related uncertainty can be included into the model. The reasoning will be made clearer in the revised manuscript.*

Paragraphs from L560 to 590: although discussion of anoxia is important it is inserted between the two paragraphs on the source of the material and seasonal differences of supply. Furthermore, Authors repeat some of the information. Please, consider reworking this section.

--> *The revised manuscript will not include this information as the geochemical data will be removed.*

Paragraph from L635: I advise caution in the Mn/Fe interpretation, even if these are mostly uncorrelated to lithogenic inputs. Seasonal relations are of importance.

--> *This is noted for future work and the revised manuscript will not include this information as the geochemical data will be removed.*

Paragraph from L645: what about sediment focusing? Also, it seems that you started writing "C.E." from here on rather than previously used "CE".

--> *The revised manuscript will ensure consistent use of CE or C.E. Sediment focusing will be added to the possible reasons.*

Figures:

Figure 1: Color for vegetation is virtually the same as depth of 0 meters of the lake. Outline the lake and catchment, so legend/key and scale are separate entities. Elevation – see comment to L89. Inflow line in the key and on the map is narrow and hard to see. Caption: Columbine Lake.

--> *This is noted and will be changed in the revised manuscript.*

Figure 4: Reconsider legend/key placement and structure. For example, varve types corresponding to the color bars in (a) are at the bottom of the box, and easy to omit.

--> *This is noted and will be changed in the revised manuscript.*

Figure 5: Is it correct to describe the dendrogram as constrained or not, or rather it is a dendrogram showing the results of constrained clustering method? (b) increase contrast of the vector groups?

--> *Good point, the latter is correct. This will be removed from the revised manuscript when the geochemical data is removed.*

Figure 7: Figure shows an impressive improvement of the chronologies once they are integrated with the results of the radiometric dating methods. Yet, this part is discussed later in the paper, with figures in between.

--> *The revised manuscript will focus more on the improvement of the chronologies and with the geochemical data removed will get to the point quicker.*

Figure 8: Some of the figure caption is a repetition of the text, rather than figure description.

--> *This is noted and will be changed in the revised manuscript.*

Figure 9: missing "l" in model.

--> *This is noted and will be changed in the revised manuscript.*

Figure 10: Any comment on multimodal distribution?

--> *This comment is well noted and an explanation will be provided in the revised manuscript. From Figure 10, 2-3 modes can be seen in all models and for all observers. Because the modes are relatively consistent, they are likely to be real rather than artifacts of the models and thus may represent different modes of deposition. In the revised manuscript we will compare the modes to the different varve types to see if they are associated.*

Figure A2: Consider adding depth/length scales.

--> *This is noted and will be changed in the revised manuscript.*

Figure A4: How was the Mn/Fe ratio normalized?

--> *Using the element Ti. This figure will no longer feature in the revised manuscript.*

Figure A6: Matter of preference, but warmer color is associated rather with positive values and colder with negative, regarding correlation.

--> *The figure will no longer be part of the revised manuscript.*

Please check figures and their captions in the text and Appendix for consistent use of (A), (B) and so on. For example, Fig A1, A5, A7 – capitalized, whereas others are not.

--> *This is noted and will be changed in the revised manuscript.*

Code:

Please think about very short readme file describing the actual workflow and data structure to reproduce your research.

--> *Agreed, a readme file will be added.*

It seems that in the "varveR_Gibbs-v.1.0.0" there are missing extensions in the R scripts, which I assumed for the review to be typical ".R" files.

--> *The extensions were accidentally omitted when the codes were transferred to Github which then transferred to Zenodo and the downloadable zip file. This will be fixed for the revised manuscript.*

If the Authors consider releasing the same scripts with the Manuscript please check the code for instances like below, where full paths are provided.

readLipd("D:/OneDrive for Business/..."); I cut the remaining path for clarity. Consider using here::here() or likewise so code is more reproducible. After this point **I did not** change all the paths to run the code.

Overall, code is commented, and consecutive blocks are explained. Examples are provided for functions and parameters are described. For the future releases of varveR some code cleanup is necessary, though.

--> The Gibbs sampler and model code will be revised for the revised manuscript, and we agree the varveR code could use some additional attention in a future release to increase usability.