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Interactive comment on "SISALv2: A comprehensive speleothem isotope database with multiple age-depth models" *by* Laia Comas-Bru et al.

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Dear Jud W. Partin,

Thanks for your comments and suggestions. Indeed, data compilations are an enormous community-based effort that we believe will have a strong impact on how science is done. Please, find our answers below highlighted in blue.

Can you please describe in more detail how the 95% confidence intervals are calculated (line 227) in the SISAL chronologies? I'm not sure, but I think it is the 95% spread in the ages using all of the age models, i.e. the spread in the curves in Figure 5 a and b. If so, I wholeheartedly support this idea. If not, then please describe in more detail.

The 95% confidence intervals are the spread for each type of age model separately not the spread considering all of the age models. Specifically, the SISAL chronology table has three columns per age-depth model technique. The first is the median age-depth model and the other two are their corresponding 2 sigma confidence intervals. These confidence intervals have been calculated from the spread of the individual ensembles for each technique that support this approach (specifically, linear interpolation, linear regression, Bchron, Bacon, OxCal and copRa)) and the last 1000 have been kept – and made available – for further analyses. For StalAge we report the uncertainties of the returned age model which are internally calculated and based on iterative fits as well as dating uncertainty. Fig. 5a and 5b show the median age models for each technique (the mean for StalAge). Each of these lines has corresponding confidence intervals which are individually reported.

We have not attempted to merge all SISAL chronologies for any given entity. Different modelling approaches give stronger weighting to some age determinations, so averaging across several methods could yield age-depth relationships that are unrealistic and/or not robust compared to the available U-Th dates.

We will add a statement on how the uncertainties are obtained in the description of each age-depth model technique in section 2.1.

Lines 204-210 are hard to follow. (Author's comment: Please note that we have separated this comment from the paragraph above as it refers to different things).

Original text in L204-210 copied for reference: "The conception and the test of the R workflow, integrating all methods but OxCal, was outlined in Roesch and Rehfeld

(2019) and includes automatized checks for the final chronologies except for OxCal. The quality control parameters obtained from OxCal were compared with the recommended values of Agreement Index (A) larger than 60 % and Convergence (C) larger than 95 %, in accordance with the guidelines in Bronk Ramsey (2008). In addition to both model agreement and P-Sequence convergence meeting these criteria, at least 90 % of individual dates had to have an acceptable Agreement and Convergence themselves. OxCal age-depth models failing to meet these criteria were not included in the SISAL chronology table."

We acknowledge that this paragraph needs rewriting and we will add the following text instead:

"We used an automated approach to age-depth modelling in R because of the large number of records. Roesch and Rehfeld (2019) have described the basic workflow concept and tested it using all of the age-modelling approaches used here except OxCal. The basic workflow involves step-by-step inspection and formatting of the data for the different methods, and the use of pre-defined parameter choices specific to each method. Each age-modelling method is called sequentially. An error message is recorded in the log file if a particular age-modelling method fails, and the algorithm then progresses to the next method. If output is produced for a particular age-modelling method, these age models are checked for monotonicity. Finally, the output standardization routine writes out, for each entity and age-modelling approach, the median age model, the ensembles (if applicable) and information of which hiatuses and dates were used in the construction of the age models. These outputs are then added to the sisal-chronology table (Table 2). All functions are available at https://github.com/paleovar/SISAL.AM *(last access: 23 July 2020) and CRAN (*https://cran.r-project.org/web/packages/rbacon/index.html*; last access: 31 January 2020).*

The general approach for the OxCal age models was similar, and step-by-step details and scripts are provided in https://doi.org/10.5281/zenodo.3586280 *(Amirnezhad-*

Mozhdehi and Comas-Bru, 2019). The quality control parameters obtained from OxCal were compared with the recommended values of Agreement Index (A) larger than 60% and Convergence (C) larger than 95%, in accordance with the guidelines in Bronk Ramsey (2008), both for the overall model and for at least 90% of the individual dates. OxCal age-depth models failing to meet these criteria were not included in the sisal-chronology table (Table 2)."

We agree that the spread of the median age models is useful. However, we do not think it is useful to calculate cross-model uncertainties based on the medians/ensembles of all age models. As explained above, in many cases the resulting merged chronology would not be consistent with the available U-Th dates. However, we supply all the data (medians, uncertainties, ensembles) so that this could be done by individual researchers on an entity by entity basis. Medians and uncertainties are available in the database and ensembles are stored in zenodo: http://doi.org/10.5281/zenodo.3816804 (Rehfeld et al., 2020).

Our approach does not penalize records with many dates. Usually, the better the spread in dates along a speleothem sample, the more constrained the age-depth model, and the lower the final uncertainty of the best-estimate median age model. However, it should be noted that this is not the case when there is a large number of conflicting U-Th dates with high analytical and correction uncertainties as the resulting age-depth model realisations will substantially differ amongst them.

For example, in Figure 5, there are a string of ages from 3400 – 3550 year BP that all follow each other. For this region of the d18O curve, there is fairly good agreement between the various age modeling techniques. Therefore, when all of those ages are viewed together, our confidence in the timing of any d18O excursion is less than that based on the error bars on each individual date (seen by less 'blur' in Figure 5c between the alternate age models). In other words, the multiple ages help to decrease our uncertainty to less than that of the analytical error bars on each U-Th dates. It's a bit

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like decreasing the signal to noise ratio by taking more measurements (by the square root of N). (Again SISAL may be doing this, but I'm not sure)

We agree with the reviewer that taking into account multiple chronologies for a given record provides more insights into the age-depth relationship. However, given that all the age models are consistent with the available dates, none of the individual chronologies should be discarded by default. Merging the chronologies obtained using different techniques to obtain "master chronologies for all the SISAL records would lead to a bias towards certain age-modelling approaches. For example, age models created using linear interpolation (successful 403 times) or Bchron (successful 420 times) would usually have a larger weight in a master chronology than Oxcal (successful 106 times) or linear regression (successful 182 times). Unless there is other information that suggests one age model type is better than others for a specific entity, all the chronologies should be considered equally likely.

To quantify the degree to which multiple age modeling techniques may reduce temporal uncertainty, I recommend that this manuscript includes a plot of the average of the analytical error in a record versus the average SISAL 95% chronology error in a record (i.e. average of 5b). Is the fit to that scatter plot a 1:1 line? Or is there a systematic reduction in the error across many records in the database b/c of time periods like 3400-3550 BP in Figure 5? Or do problematic areas, like unresolved hiatuses, compensate the reduction in errors for when the age model is tightly constrained? This would be an enlightening plot.

We do not expect a systematic reduction of the error as a result of the age-depth model techniques used and the data shows that the SISAL uncertainties ultimately depend on the uncertainties of the original U-Th dates and their spread/consistency. In any case, however, this would depend on the robustness of the approach used treat the uncertainties in each age-depth model.

As suggested by the reviewer, we will add a plot of the average analytical error per record vs the average SISAL chronology uncertainty as attached. The accompanying text will be:

"The published age-depth models of all speleothems are accessible in the original-chronology metadata table and our standardised age-depth models are available at the sisal-chronology table for 512 speleothems. Temporal uncertainties are now provided for 79% of the records in the SISAL database. This is a significantly larger number than in SISALv1b, where most age-depth models lacked temporal uncertainties. Most speleothem records show average U-Th age errors between 100-1,000 years (Figure 6), which are only slightly changed by using age-depth modelling software. Nevertheless, when comparing the mean uncertainties of the U-Th ages with those of their corresponding age-depth model, the slope between both parameters is smaller than one. This indicates that age-depth models tend to reduce uncertainties especially when dating errors are large while they increase uncertainties, when U-Th age errors are small."

Please give more detail in the text of the principles used in your calculations for when the SISAL chronology decides that there is a hiatus in the record. While you reference Breitenbach, 2012, it would be good to review the guiding principles that SISAL is using in lines 83-86 in more detail to make the manuscript more self contained. Also, what happens if there is disagreement among the various techniques about a hiatus – how does SISAL decide on a 'yes' or 'no' to split the record? Does majority rule??

Our age-depth model calculations use the U-Th dates and the depths of the hiatuses as entered in the database and which were provided by the researchers that produced the raw data and/or their publications.

We do not decide in our workflow whether there is (or should be) a hiatus in a section and therefore, all AM approaches use the same input data. For clarity, the input variables for the sisal chronologies are: depths of dating samples and isotopes, U-Th corrected ages and their uncertainties (if used to create the original or published age model), depth information of hiatuses if applicable, information on whether the speleothem was actively growing when collected and the year of collection. We did not attempt to assess whether the information provided by the data contributors/publications was correct. However, together with experts from the SISAL age modelling group we have checked whether the dates and hiatuses were visually consistent with the rest of the data.

We believe there is a misunderstanding as lines 83-86 refer to age reversals that occurred during the construction of the sisal chronologies instead of hiatuses:

"Major challenges arise through hiatuses (growth interruptions) and age reversals. In the classification of the reversals, we distinguish between tractable reversals (with overlapping confidence intervals) and non-tractable reversals (i.e., where the two-sigma-dating uncertainties do not overlap) following the definition of Breitenbach et al. (2012)."

We will rephrase this paragraph to clarify this point:

"Major challenges arise through hiatuses (growth interruptions) and age reversals. We developed a workflow to deal with records with known hiatuses that allowed the construction of age-depth models for 20% of the records with one or more hiatuses (Roesch and Rehfeld, 2019; details below for each age-depth modelling technique). Regarding the age reversals, we distinguish between tractable reversals (with overlapping confidence intervals) and non-tractable reversals (i.e., where the two-sigma-dating uncertainties do not overlap) following the definition of Breitenbach et al. (2012). Details such as the hiatus treatment and outlier age modification are recorded in a logfile created when running the age models. We followed the original author's choices regarding date usage. If an age was marked as "not used" or "usage unknown", we did not consider this in the construction of the new chronologies except in OxCal, where

dates with "usage unknown" were considered."

Details on how each technique tackled the hiatuses are copied below (with their corresponding line numbers):

Linear Interpolation: "Hiatuses are modelled following the approach of Roesch and Rehfeld (2019), where rather than modelling each segment separately, synthetic ages with uncertainties spanning the entire hiatus duration are introduced for use in age-depth model construction. These synthetic ages are removed after age-depth model construction. " **(lines 100-104)**

Linear Regression: "If hiatuses are present, the segments in-between were split at the depth of the hiatus without an artificial age. " **(lines 110-111)**

Bchron: "Since Bchron cannot handle hiatuses, we implemented a new workflow that adds synthetic ages with uncertainties spanning the entire hiatus duration (Roesch and Rehfeld, 2019), as performed with linear interpolation, StalAge and our implementation of COPRA. " **(lines 116-118)**

Bacon: "The R package rBacon can handle both outliers and hiatuses and apart from giving the median age-depth model, (. . .)." **(lines 125-126)**

Oxcal: "OxCal can deal with hiatuses and outliers and accounts for the non-uniform nature of the deposition process (Poisson process using the P-Sequence command). " **(lines 134-136)**

COPRA: " (. . .) we implemented a new workflow in R that adds artificial dates at the location of the hiatuses and prevents the creation of age reversals (Roesch and Rehfeld, 2019) as done with linear interpolation, StalAge and Bchron. " **(lines 150-152)**

StalAge: "The StalAge v1.0 R function has been updated to R version 3.4 and the default outlier and reversal checks were enabled to run automatically. Hiatuses cannot be entered in StalAge v1.0, but the updated version incorporates a treatment of hiatuses based on the creation of temporary synthetic ages following Roesch and Rehfeld

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(2019). ” **(lines 160-163)**

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