

Review of CP-2020-110 “Climatic variations during the Holocene inferred from radiocarbon and stable carbon isotopes in a high Alpine cave” by Welte et al.

**General comments:**

This paper could be of great interest to scientists challenged with properly disentangling the controlling factors of  $\delta^{13}\text{C}$  in caves, which is quite complex as has been reviewed recently by Fohlmeister et al. (2020, GCA).

The strength of the paper is the combination of radiocarbon concentration and  $\delta^{13}\text{C}$  in stalagmites samples at a continuous and high spatial resolution to understand what happens above the Spannagel cave during some period of the Holocene. However, I found that the manuscript is moderately written (please don't take this personal, and as a reviewer I am not qualified to comment in detail about the writing, but I strongly believe there is a room for improvement and writing is a learning process). Also, in my opinion, the manuscript requires a lot of reorganization of ideas to make it clearer. For example, the first section of the discussion section, the anomalies in the old section of SPA 127 do not highlight the importance of the proxies being studied. Instead, it discusses the result based on methodological approach. Please note that the journal “Climate of the Past” is not a methodology journal (if this paper was submitted to a method paper, then I would not argue about having this part in the discussion). In fact, I see that this whole section either belongs to the method or some part of it could go as a quick interpretation of the data in the result section, but it should not belong to the discussion section. Another example, a separate generality section about  $\delta^{13}\text{C}$  can be helpful here (see detailed comments) where the authors could explain the difference between radioactive  $^{14}\text{C}$  and dead carbon, and what are the potential sources of them. With this said, the sections at L 67-105 could belong to that independent section right between the introduction and the Materials & methods. If that general & fundamental notion is separated from the introduction, I am certain that the introduction could become concise and clearer, with a clear statement of the problematic, and a proposition of the new method and its potential relevance in future paleo- reconstruction.

I also feel the title does not fully capture the content of the manuscript. While the authors entitled their manuscript “Climatic variations during the Holocene inferred from

radiocarbon and stable carbon isotopes in a high Alpine cave”, I found that the manuscript mainly use radiocarbon and  $\delta^{13}\text{C}$  as a proxy for local changes and specifically what happens right above the cave in the epikarst, and not directly to climate. In their conclusion, it was made clear that these two are good proxies to understand carbon dynamic. Hence, I think the authors should emphasize the importance of  $\delta^{13}\text{C}$  and  $\text{F}^{14}\text{C}$  in the use of stalagmites in paleoenvironmental reconstruction and build their discussion based on that, rather than jumping directly to climate, which at this stage seems more speculative.

There are several points by the authors in manuscript that support my comments. For example, in the abstract, the authors used the variation in  $^{14}\text{C}$  and  $\delta^{13}\text{C}$  as an evidence of host bedrock dissolution or organic matter reservoir contribution from the epikarst to the cave. And in fact, this has been one of the focuses of the interpretation/discussion. The authors should make that clear that from using such inferences, information from the local place can later be applied to climatic context. In my reading of the manuscript, the bridge ‘*local response–climate*’ is quite obscure (possibly by the current way how the manuscript has been organized, or because this aspect is still difficult to fully link with confidence). Realistic suggestion: reorganizing the ideas would significantly improve the manuscript. In addition, interpretation of  $\delta^{13}\text{C}$  is very complex compared with  $\delta^{18}\text{O}$ , although the water-rock interaction may also complicate its interpretation. Among the factors that complicate the interpretation of the C records in speleothems is the-so called PCP (or prior calcite precipitation, or to be general Prior Carbonate Precipitation, to avoid discrimination between the two common  $\text{CaCO}_3$  polymorphs, calcite and aragonite). Could this factor influence the proxies being investigated in this study? E.g., for the large range (-8 to +1 per mil)?

Minor but crucial: There are some confusing technical terms used in the manuscript that need to be specified. For example, the word ‘precipitation’. The authors should specify if the precipitation reflects *rainfall* which is climate or if it represents the *carbonate precipitation* leading to the formation of speleothems.

To summarize my general comment, I see that the dominant aspects of the hypotheses are focused on the local processes that may affect the carbon stable composition. The paper and the research are interesting, but there is plenty of room for

improvement. I hope my general comment and the detailed comments would help improving the paper.

### **Detailed comments:**

L28- Please rephrase first sentence as: "Rapid and continuous analysis of radiocarbon concentration in carbonate samples at high resolution has been possible with the new LA-AMS technique."

L30: time

L42-43: I do not fully understand this mechanism, and it needs to be elaborated more

L47: I think there are some missing perspective remarks at the end of the abstract

L52: Fairchild et al. 2006: are you sure this is the best representative reference here?

L53: "except" Antarctica

L57: add a relevant literature reference after signal

L59: extra brackets (please remove, and anywhere in the manuscript)

L57-60: There is a recent paper by Fohlmeister et al. 2020, GCA that could be of relevance to this paragraph

L67: Some basics about dcf (as noted in the general comments), that could be an independent general context apart from the introduction

L72: "if a radiocarbon independent..." : why *if*?

L77: Values of dcf? (please specify)

L78: "commonly vary within a single speleothem with time" : reference please? Earlier you said no data still availabilities statement is therefore not proven nor supported by data?

L85: reference please?

L88: several studies? May be better to say two studies (as only two references are provided). Otherwise, please be accurate.

L89: dcf in what?

L90-92: I do not fully understand this statement, how can rainfall accelerate SOM decomposition?

how does rainfall increase the mean age of soil gas CO<sub>2</sub>?

L93: from some of the points in this paragraph, and looking back at the title, wouldn't it be more appropriate to use these two proxies for dissolution rather than climate?

Table 1: The context of these given values are not fully clear. Please explain in the table caption, and indicate under what type of vegetation cover?

L106: Please rewrite as “the studied stalagmite grew....” And please add the Lat/Long of the cave

L109: add a relevant reference for the geological aspect of the region

L134: what does “in situ” imply? , and please add a reference supporting that it was not ice covered during the Holocene (L135)

L160-163: aren't there be any markers in the stalagmite layers to match the wiggles? (please also seem more comments further below)

L218, 240: is it 14C or was there a typo?

L246: are displayed

Figure 4c: would be informative to see the age uncertainty by analysis, and the StalAge model with corresponding confidence interval. Where there is a discontinuity at 7.5ka?

L259: please add relevant reference as a guide for readers

L265-268: Please remove, if the structure of the manuscript is clear enough, this speech-kind of text can be easily removed. It brings no relevant information to understanding the significance of research.

L271: please refer to corresponding figures

L272: What bulk are you referring to?

L270–277: should belong to a short interpretation of the results. It does not give value to the title of the manuscript, which the authors should highlight the importance of F14C in paleoenvironmental reconstruction

General: This whole section 1 of the discussion can either belong to the method or part as a quick interpretation of the data, but it should not belong to the discussion section.

The authors should emphasize the importance of  $\delta^{13}\text{C}$  and F14C in the use stalagmites in paleoenvironmental reconstruction

L310: epikarst (instead of karst), and please add a relevant reference at the end of the sentence at L311

L311-312: There are some contradictions here. More  $\text{CaCO}_3$  dissolution does not mean nor imply higher growth rates. More dissolution may suggest more acidic solution, and thus supersaturation in  $\text{CaCO}_3$  was not achieved to allow calcite or aragonite to precipitate.

L313: please remove indeed

L314: Mangini et al. 2005: this reference is missing

L320: please correct for the typo. Also, do you mean here rainfall or CaCO<sub>3</sub> precipitation?

L327: precipitation: please specify

L332: few re-writings suggestions: End the first sentence at “period.” Then start with “The first is from soil CO<sub>2</sub>.... The second is from sulfuric acid....

L335: is it known how fast changes in soil d<sup>13</sup>C is transferred to speleothems?

L337-339: any references for this?

L340: why modern?

L344-345: this could be corrected prior to making comparison (see comment below)

L350: This is an instructive remark; however, it may be worth comparing (see comment below)

Comment about this paragraph: My problem with this part is that there is no correction done on the dft for d<sup>13</sup>C and <sup>14</sup>C, but then the author commented on the correlation between the two variables. This aspect weakens the paper, because the authors could have done it better. For example, if the scanning speed of the laser is known (plus, they provide the spot size of the laser beam), it is possible to define the dft of the high/low peaks in the LA scans with the dft of the d<sup>13</sup>C. By selecting about 15–20 key points in the <sup>14</sup>C data, I think it is possible to connect the <sup>14</sup>C profile with the d<sup>13</sup>C profile with better accuracy.

L352-353: how about PCP?

L365: fast dripping =>fast growth: not necessarily. Fast drip sites in cave may be characterized by undersaturated solution with respect to CaCO<sub>3</sub>, and may not lead to CaCO<sub>3</sub> precipitation (but instead, corrosion of the earlier deposited carbonates)

L370: low drip rate may in some cases increases the CaCO<sub>3</sub> precipitation rates, unless the number of drops/sec is very slow, and hence could lead in hiatus in deposition

L378: Fractionation effects: please be precise, this title is quite vague

L381: lighter molecules change.... Please rephrase, it reads awkward

L382: Please delete : “this is valid for <sup>13</sup>C and <sup>14</sup>C isotopes”. The statement does not bring any novelty

L386: any figures for reference here?

L388–390: the authors should elaborate on this with one or two sentences

L392: FigA7: this figure does not exist? Or did I miss it?

L398: long drip interval: I think if drip interval is long, this could enhance degassing/evaporation

L403: which is approximately -8permil (and please add reference)

L408: ref. please?

L428-431: here the authors clearly state that their approach could bring light on understanding processes affecting C isotopes in the subsurface (one of the reasons I made a comment about the mismatch between the title and the content of the manuscript)

L442: contributed CO<sub>2</sub> to CaCO<sub>3</sub>: this is awkward, please rephrase

L463: why only CO<sub>2</sub> (shouldn't be DIC that is more appropriate?)

Figure 6 is very confusing to me; I am not fully sure what information to take from here?

What is the importance of elevation in F14C?

L477: Re-writing suggestion:

“Results from this study allow to distinguish three intervals with different carbon dynamics.

(1) The interval before 8ka BP....

(2) The interval between 8–3.8ka BP (switch the number to follow the temporal logic)

(3) .....

L479: potentially enhancing bedrock dissolution.