<u>Response to Reviewer 2</u>

Thank you for the supportive comments and suggestions to improve our manuscript. We have taken the suggestions onboard and will edit the manuscript according to the following responses.

This paper investigates the subsurface CO2 dynamics in the Milandre cave karst system in northern Switzerland, focusing on seasonal and spatial variations. The study spans several years and involves analyzing CO2 concentrations, stable carbon isotopic ratios (δ13C), and radiocarbon (14C) compositions from various sources, including the outside atmosphere, boreholes, and cave air.

Key findings include i) that CO2 concentrations in shallow boreholes are higher in summer due to increased respiration rates and lower in winter, ii) cave CO2 concentrations and isotopic compositions are influenced by temperature-driven seasonal ventilation, iii) the cave air CO2 levels were anti-correlated depending on where exactly in the cave the measurements were obtained, and iv) that the CO2 in the cave is primarily sourced from modern soil respiration and aged organic material in the epikarst.

The research highlights the complexity of CO2 dynamics in karst systems and the significant impact of seasonal and ecological factors on carbon cycling within the terrestrial Critical Zone. It is sound research reflecting the results of a long and intense monitoring campaign, and I recommend publication following the minor revisions suggested below.

There is a substantial amount of text devoted to describing the data, but a bit more describing the characteristics of the site with respect to carbon would be useful. For example, is there organic sediment within the cave site? How deep are the deep roots in the forest? Related to the above, I could not find the depth to the cave anywhere. It could well be here (apologies if so), but could it be included in the site description section? There is the sentence 'The unsaturated zone ranges between 40 and 80 m depth, with a saturated zone of ~ 20 m' but the cave could be developed anywhere within the unsaturated zone, so this does not let the reader know where the cave is relative to the surface. This is really critical for the interpretations presented here; for example, do the tree roots reach the cave? Also, why is the saturated zone only 20 meters? What is below the saturated zone?

Thank you for this detailed comment. We will improve the description of the Milandre site with more specific references to the cave sediments, unsaturated and saturated zone. The exact depth of the tree roots is not known, however there are no tree roots visible within the cave itself. We will be more specific with regards to this section.

The unsaturated reaches down to between 40 and 80 m below surface. The active karst level develops in the epiphreatic zone. The underneath phreatic zone extends for c. 20m to reach the low permeable Lower Oxfordian marls (Liesberg Mb) which act as a regional aquiclude. The site description will be amended to describe the stratigraphy more explicitly.

Line 48: Suggest rephrasing 'exclusively aged CO2 reservoirs' – a bit awkwardly phrased

Thank you, we will rephrase this to "...CO_2 reservoirs of a lower $F^{14}C$ corresponding to an older age" to improve the clarity.

Line 60 (and throughout): the comma in the 1,000s separator in the numbers should be on the bottom rather than the top.

Thank you, we will change the commas to be on the bottom when reporting numbers.

L69: 'provenance' not plural

Thank you, we will change this to "provenance".

L112: Elaborate – if it was built in house, why is there a brand name? Also spell out 'nondispersive infrared (NDIR)' for readers who may not be familiar with acronym

We thank the reviewer for this comment. The casing of the sensor was in-house built but the information is not really needed here.

We suggest adding this sentence "The CO_2 concentration was monitored during line flushing using a nondispersive infrared CO_2 sensor (SCD30, Sensirion, Switzerland) to ensure accurate sampling."

L138 and elsewhere: 'through trip' rather than 'cross trip'

Thank you, we will change "cross trip" to "through trip" throughout the manuscript for clarity.

L201-202: Technically this is all correct, but consider using either 'r' instead of the letter 'rho' or spell out 'rho' instead of using the letter. It looks a lot like the 'p' in p-value, and this would avoid some confusion. But up to the authors.

Thank you for catching this, we will replace all the "rho" symbols to "rho" the word.

L207: Use 'average' or 'mean' but be consistent. On this line both words are used in the same context. I'd recommend 'mean' when talking about a statistical quantity and 'average' when talking about something in general terms.

Thank you, we will change the use of "mean" and "average" as suggested throughout the manuscript.

Figure 2: Consider writing 'C3' and 'C4' and putting the text inside the filled boxes. Or connect the labels to the boxes with a connector line. The issue is that where they are now makes it seem like where the actual field is, and some readers might not notice the boxes. The same is very true for the blue atmosphere box – it is almost invisible. I definitely recommend drawing a line or an arrow between the text and the blue box in that case.

We agree that the legibility of this figure is lacking and will improve it by connecting the labels to the boxes and changing the colour of the boxes so it is more clear.

Figure 2: Use 'Upstream (Cave air)' and 'Downstream (Cave air)' in the legend, this might make it clear that these are in-cave measurements. It is clear from the text, but someone scanning the paper would be forgiven for thinking you had somehow taken these measurements from a stream.

Thank you for pointing this out! We will edit the legend accordingly.

Figure 3: It might be useful to show atmospheric CO2 concentration and chemistry here as well?

We agree that it would be useful to be able to compare to the atmospheric values, however adding this information to the figure would mean that the trends of the borehole CO_2 would be less clearly visible in the concentration (a) and $\delta^{13}C$ (b) graphs. We find it sufficient that the atmospheric values can be compared to the cave and borehole samples in Fig.2 and Fig.7.

Figure 3 and elsewhere: Why are there a maximum and minimum numbers for each timeslice? I assume that this is max and min of the monthly recorded values? I feel that this is probably

obvious - but i can't find it. So, if it is in the manuscript, it should be made more apparent, including here in the figure caption.

The maximum and minimum values are presented here because in these boreholes there are multiple sampling lines which sample over a depth range (see Table 1). However, due to the nature of the installation of these lines, we cannot distinguish between each depth. Therefore, we just present the maximum and minimum values which represent the range of CO_2 sampled from these boreholes. We were edit the text and the figure caption to more clearly state this.

L263: Is this truly referring to the epikarst (the relatively shallow zone of fractured rock directly beneath the soil), or is this bedrock within the unsaturated zone? Earlier, you use the term unsaturated zone, and the depths of the boreholes seem deeper than the epikarst, so I think you mean might mean unsaturated zone. The two have different meanings, and not interchangeable. Similarly, 'karst' refers to all the karstified limestone bedrock, regardless of whether it is saturated or unsaturated – it is not just the rock above the cave. Please change to appropriate terminology if these terms are used incorrectly. If they are used correctly, you might want to consider defining the term 'epikarst' since it is so often used incorrectly. This way readers will know for sure that what you are referring to as the epikarst is the irregular surface between the karst and the soil.

Thank you very much for pointing this out! Indeed, we use the term "epikarst" and unsaturated zone interchangeably which is not correct. We will edit the manuscript throughout to use the correct terms.

L418: How does borehole Deep 1 influence the correlation? I think needs to be reworded.

We thank the review for pointing this out. We think that this sentence is in fact an error, as there is no significant correlation between pCO_2 and MMT for Deep 1. We will delete this sentence accordingly.