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# ***Interactive comment on “Seasonal variations recorded in cave monitoring results and a 10 year monthly resolved speleothem $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ record from the Han-sur-Lesse cave, Belgium” by M. Van Rampelbergh et al.***

**Anonymous Referee #1**

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Van Rampelbergh and co-authors report detailed data from a regular cave monitoring campaign from Han-sur-Lesse cave in Belgium. The campaign in this show cave was conducted from November 2012 to January 2014. Each two weeks they obtained data for various cave parameters as temperature (atmospheric, cave and drip water), meteoric rain, cave air pCO<sub>2</sub> and stable isotopes (of CO<sub>2</sub>, dissolved inorganic carbon and carbonate). The monitoring data were adequately discussed. The discussion was lead with the aim to understand the variations of the oxygen and carbon isotopic composition of recently - on glass plates - precipitated calcite and from one short but

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fast growing part of a stalagmite from this cave system. The data are new and essential to understand cave related processes, which is necessary to interpret time series of stalagmite stable isotope proxies in terms of climate variations. The paper is well written and structured. The discussion is clear and for most parts solid. (Please find more information about this in the 'specific comments' section.) Finally, to my opinion, the data support the final interpretation. Therefore, I think that this paper meets the publishing criteria for Climate of the Past. The paper should be published in CP after implementation of a few modifications and addressing the points raised below.

#### specific comments

Han-sur-Lesse cave is a famous show cave. I guess that several thousand visitors per year go through the whole cave system. Such large number cannot be neglected for the cave atmosphere. They all respire CO<sub>2</sub>, for example. This might have an impact on the measured cave parameters and should be discussed. For example, during summer the number of visitors is certainly higher than in autumn or winter. This introduces maybe some artificial seasonality to the cave system (T, cave air CO<sub>2</sub> and d<sub>13</sub>C). I feel that a discussion of this aspect is necessary within this paper.

In addition, I think that the characteristics of the Lesse River are also underrepresented in the discussion of this paper. Cave temperature might be not only influenced by mixing with outside air induced by the river (P 1833, I 22). In addition, the water of the river might transport a lot of energy from outside (gained before it enters the cave) to the inner cave. This heat might then be released in the cave with more impact in the warm months than in the cold.

Another point is that I would like to read a few words about prior calcite precipitation and if it is important for this site (e.g., is there a big or small stalactite above the stalagmite or is there other evidence). Unfortunately nothing is mentioned in the text about this effect. However, this would provide a better overview about the cave system and cave related processes.

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While the previously mentioned comments might be regarded as additional information, which are helpful for the reader to understand the cave system, I think that the discussion about the seasonally varying pH needs to be more precise and redirected (P 1834, l 17 and the whole paragraph). In fact, I think the whole discussion about the pH is not correct. The reason, why I think like that is the following. I agree with you completely that the cave drip water is well mixed throughout the year, as indicated by the relatively constant drip water  $\delta^{18}\text{O}$  and  $\delta\text{D}$  compared to the isotopic composition of the precipitation. However, I do not see the point, why the pH value, which certainly varies in the soil with the seasonally variable soil air  $\text{pCO}_2$ , should not be affected by this mixing process. Either the water is well mixed before entering the cave and there is no difference in all the chemical parameters, or it is not. Since,  $\text{CO}_2$  dissolution in the soil and  $\text{CaCO}_3$  dissolution in the karst are believed to be rather fast processes (E.g., Dreybrodt and Scholz, GCA, Vol 75, p 734 - 752, 2011), at least if compared to the water mixing time above Han-sur-Lesse cave, and hence occur mainly in the upper part of soil-karst-system, those processes should not be important for variations in the drip water pH. To my opinion, it is a better concept to accept the well mixed water reservoir above the cave and assume more or less constant values year-around for the various parameters of drip water before entering the cave. Then another process is necessary for the variations in the pH values. I think that the cause of this pH variation is due to a variable amount of degassing of  $\text{CO}_2$  from the drip water. The amount of  $\text{CO}_2$  degassing is a function of cave air  $\text{CO}_2$ . The amount of cave air  $\text{pCO}_2$  would define the maximum amount of  $\text{CO}_2$ , which is able to degas. The lower the cave air  $\text{CO}_2$ , the more  $\text{CO}_2$  can degas from the solution resulting in a higher pH of the water. This process is slightly modulated by drip rate, since with fast drip rates it is possible that complete  $\text{CO}_2$  degassing is not achieved due to a too fast succession of following drops. Therefore the expected anti-correlation between cave air  $\text{pCO}_2$  and drip water pH is not expected to be perfect.

P 1838, l 8: You wrote that  $\delta^{13}\text{C}$  of dissolved inorganic carbon does not show a seasonal cycle. Well, I would say, that one can have another opinion about this issue.

There is also a quite good reason, why the annual cycle might be visible although the water is well mixed. If indeed the degassing of CO<sub>2</sub> drives the pH variation, then this degassing affects also the δ<sup>13</sup>C of the DIC in drip water. More degassing during periods of low cave air pCO<sub>2</sub> would result in a larger loss of preferentially light C isotopes. Hence the δ<sup>13</sup>C of DIC is expected to be less negative during periods of low cave air pCO<sub>2</sub> - as it is observed.

Technical corrections

P 1825 | 11: isotope

P 1826 | 7: Please, delete 'in' after 'heavy'

P1827, I 2-3: Is it likely that water temperature adjusted itself to the room temperature, while stored in the pool on top of the stalagmite? That would mean the water temp was initially somewhat colder during penetration to the cave.

P 1828, I 22: I guess 'evaporation' is not the right word here. Instead, I suggest using the term 'diffusion'. This is probably, what you meant.

P 1830, I 2: remove the ‘.’ in front of ‘in early June’.

You mention your present Figure 5 (P 1831) before Figure 4 (P 1840). Please change this accordingly.

P 1832, I 8: 'These drops do not ...'

P 1833, I 8 and 13: In these lines you stated that the delay is five to six months. However in Fig. 3 you wrote the delay is 4 months. Please clarify this and be consistent.

P 1833, I 20: Here you state that the mean cave air temperature is about 1°C warmer than the mean trip water temperature. A few pages before the offset was only 0.5°C (P 1829, I 24). Please clarify this and be consistent.

P 1838, I 2: I suggest to delete the text in the brackets. This gives no additional

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information.

P 1838, I 5-6: To be more precise, I think you should rephrase your point (ii). The fractionation factors are indeed important for the  $d_{13}C$  composition of the carbonate, but those factors are mainly driven by temperature in this pH range.

P 1838, I 21: Do you mean 'disequilibrium'?

P 1838, I 29: 'stronger' should be included before 'enrichment', because an enrichment in  $d_{13}C$  is all the time observed, no matter how large the  $pCO_2$  difference is.

P 1839, I 21: 'CO<sub>2</sub> degassing is more important'. As I understood the theory in the cited papers your argumentation is not completely true. CO<sub>2</sub> degassing is all the time really fast and has only a minor effect on the final  $d_{13}C$  of precipitated CaCO<sub>3</sub> (see for example Dreybrodt and Scholz, 2011). It is the CaCO<sub>3</sub> deposition, which has more time, with a slower drip rate. This process in addition to the typical characteristics of a Rayleigh fractionation is responsible for higher  $d_{13}C$  values in precipitated calcite.

P 1839, I 21: Please delete one of the two 'in'.

P 1839, I 25: Please, replace 'evaporation' by 'degassing'. No phase transition between liquid CO<sub>2</sub> and gaseous CO<sub>2</sub> occurs. It is a degassing from dissolved C to gaseous CO<sub>2</sub>.

P 1841, I 17-22: From the theory, this is fine, but you did not show the according carbonate concentration data which would indicate that your argumentation is right. And if you assume that your water is well mixed before it arrives the cave the carbonate ion concentration should be more or less constant. However, as the drip water comes into contact to the cave air prior calcite precipitation might occur, which would change the carbonate ion concentration.

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