

## ***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 #2**

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This manuscript presents a cave monitoring study from Han-sur-Lesse cave in Belgium. Several cave parameters were monitored for one year in a two weeks rhythm. The monitoring results were used to interpret an annual laminated speleothem record from this cave. This link between cave monitoring results and speleothem records is very important for the progress in understanding and interpretation of past climate variability from this palaeoclimatic archive. It is a very interesting story and a nice data set, which is a good contribution to the scientific progress. Further, the manuscript is well written and structured, but there are several points where the manuscript should be

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improved. In the following I will list general comments and suggestions and give a list of specific comments and technical improvements for the manuscript. The manuscript needs major revisions before accepting it for publication.

General Comments: It is clear that you have a monthly measuring resolution for the speleothem record and a two weeks resolution for the monitoring parameters. But you, by yourself, wrote in the paper that there is “only” a seasonal change between a summer and a winter mode, which causes the annual lamination of the speleothem. Due to this the proxy resolution is “only” on a seasonal base. Please go carefully through the complete manuscript and correct this, because you wrote this at several points. The manuscript has to be reworked in matters of clarify the measuring resolution and the proxy resolution.

In the context of the  $\delta^{13}\text{C}$  composition of the calcite, which precipitated on the glass slaps, you mention evaporation. This is wrong in the context of  $\delta^{13}\text{C}$  in drip water and calcite. I think you mean the degassing of  $\text{CO}_2$  from the drip water, which has an essential influence on the isotopic composition of the  $\delta^{13}\text{C}$  in the drip water and in the calcite. Evaporation is dependent on the humidity of the cave air and the temperature of the cave air and influences the  $\delta^{18}\text{O}$  system of the drip water and the calcite. Therefore, please go carefully through the manuscript and rework these parts and clarify that you mean the degassing of  $\text{CO}_2$  from the solution. To this topic there are several publications from Dreybrodt, Mühlinghaus and Scholz.

The structure of the Abstract could be improved by adopting the following structure: 1. Background, 2. Methods, 3. Results and 4. Conclusion.

At several points in the manuscript you give a list of references (e.g., P 1824, L 3). Please add “e.g.,” at the beginning of these lists, because it is a selection of studies which you cited and not all available once in this field.

At several points in the manuscript, for example on page 1824, line 25, you do not give the appropriate references and/or some important ones are missing. Please check the

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manuscript for this. For example (P 1824, L 25), Dreybrodt (1999) is not an appropriate reference for a study of cave dynamics. One further example (P 1824, L 28): there are some extensive monitoring studies missing for example Spötl et al. (2005).

The introduction of this manuscript could be better structured and focused. The structure should be: 1. The “problem” studied, 2. State of the art for this “problem” (findings by others), 3. The goals of your study.

In the “Study Area” you mentioned that the Han-sur-Lesse cave is a show cave where tourists are walking thorough. But in the following you did not discuss the influence of the tourist in the cave on your monitoring results. Do you measure in the cave when there were no tourists? Do you know how fast the CO<sub>2</sub> values in the cave decrease to normal values after a group of tourist were in the cave? How many tourists visit the cave every day? Are there more tourists in summer than in winter? These are important questions, which have to be mentioned and discuss in the manuscript. People in the cave have a big influence on cave air temperature, humidity and especially the CO<sub>2</sub> values. There are several publications dealing with this issue.

Results and interpretation/discussion of the data should be strictly separated. This is not always the case. Please go through the results and move all interpretation to the discussions part.

At some points of the manuscript the data are a bit over interpreted. For example the six drops in the  $\delta^{18}O$  and  $\delta^2H$  values of the rain water, which are interpret as rain events and due to the amount effect. When I take a look on the rain data, I also could see some rain events in summer, which do not have an effect on the  $\delta^{18}O$  and  $\delta^2H$  of the rain. Further, in the temperate climate zone the amount effect is very low. The most influencing factor on the  $\delta^{18}O$  and  $\delta^2H$  of the rain water is the temperature (go into the corresponding literature). The only striking thing in the  $\delta^{18}O$  and  $\delta^2H$  record from the rain water is the drop in March, which is clearly related to the snow in March. There are several other points where the data are over interpreted. Please go

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carefully through the manuscript and rework this. Always take your measuring accuracy and/or the standard deviation into account and think about if a fluctuation of your data is significantly above this accuracy and could be meaningful. Perhaps, it will help to put error bars at all data sets. I think there are also some error bars missing. For example the cave air CO<sub>2</sub> values. You said you measure three times in the cave and then averaged these values. I think they will not be exactly the same. Therefore, error bars, in this case standard deviation, are missing. Please check also the other data for this.

In the discussion part an in depth discussion and comparison of the result with other studies is missing, but this is an important part. Please read the corresponding literature.

The Conclusions have to be shortened to the half. They should include the important findings of this study and do not repeat too much of the results and discussion part. Further, they have to be adapted to the changes, which should be made in the results and discussion part.

The figures have to be adapted to a reworked version of the paper.

Specific and technical Comments in chronological order:

Authors list: Please change “M Allan” to “M. Allan”.

P 1823, L 2-3: These two sentences would fit better in the Introduction part than in the Abstract.

P 1823, L 4: It is not clear what or who is meant with “They”. Please clarify this.

P 1823, L 6: Please clarify if the thickness of 0.5 to 2 mm is related to a layer pair (dark and white layer together) or on a single layer (dark or white layer).

P 1823, L 6: A stalagmite could not reconstruct palaeoclimate. Please rework this sentence that the coherence is correct.

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P 1823, L 17: Here you did not put summer-mode in quotation marks, but before you did this. Please be consistent.

P 1824, L 3: Please replace “systems” with “variations”.

P 1824, L 9: I do not know a speleothem record with a monthly proxy resolution. If there is one please give a reference. To my knowledge the only palaeoclimate proxy, which could give a monthly climate proxy resolution are tree-ring. But also this archive show seasonal climate signals in most cases.

P 1824, L 10: What are these “limitations”? Please give a bit more information.

P1824, L 19-23: There are some studies where a transfer function between the stable oxygen and carbon isotopic composition of a speleothem to climate parameters were applied, but it is not a “well established” method in speleothem research. The interaction between the climate parameters, the soil, the host rock and the cave environment are very complex, as you show in this study and due to this a straight transfer function is not established at the moment.

P 1824, L 26: Please replace “systems” with “studies”.

P 1825, L 22: Please replace “19th” with “19th”.

P 1826, L 1-3: From this description, I think, the “Prospine stalagmite” is more a flowstone than a candle shaped stalagmite. Please replace “stalagmite” with “flowstone” in this context in the complete manuscript.

P 1826, L 3: What is meant with “high drip flow”? Is this water flowing along the surface of the Prospine flowstone? Is there a soda straw, stalactite or drapery above the Prospine flowstone from which the water is dripping on the surface? Is there one drip site or more dripping on the Prospine flowstone? This is not clear from this description. But this is a very essential point to know, because this has an influence on the interpretation and understanding of the monitoring results and further on the speleothem record. Please give some detailed information to this issue.

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P 1826, L 3: Please replace “stalagmite” with “cave chamber”, because the epikast thickness covers the complete cave chamber.

P 1826, L 4-9: This part, describing the residence and reaction time of the epikarst and the drip rate, respectively, should be moved to the results part, because these are specific results, which are essential for the interpretation of the signal in the monitoring results.

P 1826, L 9-12: This part about the ventilation pattern of the cave should as well be moved to the results part. At this part it should be only mentioned that two passages connect the “Salle-Du-Dome” to the neighbouring chambers. In general, these connections in the cave do not only control the ventilation pattern. The most important feature controlling the ventilation of a cave is the number and wideness of the cave entrances and how big is the difference in altitude between the entrances. Further, these cave conditions are very important for the interpretation of the cave air monitoring data. Therefore, please take this into account in the results and discussion part and give the necessary information about this here for the Study area. You could take a look in several of the monitoring publication for suggestions how to incorporate these informations into the manuscript.

P 1826, L 15-16: For the description of the climate please use the terms of an international climate classification (for example Köppen and Geiger). The expression that the “rainfall is spread all over the entire year” is colloquial. The correct term for this is “fully humid” (see climate classification after Köppen and Geiger).

P 1826, L 19: Please mention here that the very cold March 2013 was an exception and does not represents the average weather conditions of the month March.

P 1826, L 21: Please describe the soil with the terms of the international soil classification. Therefore, it will be understandable for everyone.

P 1827, L 2-4: The measurement of pH-value in a small pool on the surface of the flow-

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stone is not ideal. Due to the degassing of CO<sub>2</sub> from the drip water the pH is strongly altered. It is also altered, when it is measured directly after sampling of the water, but in a lower amount. Why did you not measure the pH from the water you collected in the plastic swimming pool? Or did you sample drip water for pH measurements in an extra bottle? This is not clear from the text. But never the less it should be mentioned in the manuscript, that the pH is always altered. This fact is mentioned in several publications dealing with cave monitoring.

P 1827, L 6: You measured CO<sub>2</sub> concentration in the cave air tree times per cave visit. Where in the cave chamber do you measure? This could give some information about the cave ventilation pattern, when you measure CO<sub>2</sub> near to the ceiling and at the floor.

P 1827, L 7-11: Where is the drip water coming from? Is this water flowing over the surface of the flowstone? Or is this drip water from one or more stalagmites above the flowstone? This is not clear and has to be clarified for the reader.

P 1827, L 24-25: What is the three point correction method? Is this a correction of the measured data with a linear regression line of three different standard materials with different isotopic compositions? Please give some exact information to this. Further, you mentioned the three “home made standards”. What material are these standards? Please use the term “in house standards” instead of “home made standards”. And please give the isotopic composition for all three standards for  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$ .

P 1827, L 27: Please replace “two measurement rounds” with “two measurements”.

P 1827, L 27: Do you mean the long term reproducibility of your “in house standards” with the “analytical uncertainties”? Please give the long term reproducibility of the standards in your lab, when this is not the case in the text. Further, please mention in the text to which international reference material your “in house standards” are calibrated.

P 1827, L 28: Please add that these isotopic values are given in respect to VSMOW.

P 1827, L 28: Please check the uncertainties of 0.5‰ for the  $\delta^{13}\text{C}$ . To me it seems to

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be too low for a  $2\sigma$ .

P 1828, L 6: Please make a new paragraph at the end of the sentence.

P 1828, L 18-23 and P 1830, L 17: Please check if Matthey et al. (2008) is the correct reference for this method. It is not exactly described in the same way in Matthey et al. (2008) as you describe it. Further, this method is also used by Spötl et al. (2005) during the Obir Cave monitoring. Perhaps there was a mistake in the references.

P 1828, L 25: Please give the standard material, which was used to determine the analytical uncertainty, the international reference material to which a possibly used “in house standard” was calibrated, and add VPDB.

P 1828, L 28: You took of five samples from each glass slap. Where on the glass slap you scratch of the sample? Were the glass slaps completely covered by calcite or was there only calcite on the rim? Please add some more information to this issue.

P 1829, L 1-2: Where were the glass slaps placed on the flowstone? Are they positioned under different drip sites? Or is the water flowing over the glass slaps? This is quite important due to the interpretation of the results. If there are different drip sites, which could have different drip rates, this could influence the stable carbon isotopic composition of the water and the calcite. Therefore, the values of the  $\delta^{13}\text{C}$  from the different glass slaps should not be averaged.

P 1829, L 5: Did you use a microscope for the layer counting? If this is the case please add the specific microscope you used.

P 1829, L 5: Is the age model of this flowstone only based on layer counting or were there some absolute age datings performed?

P 1829, L 9: Please replace “Merchantic” with “Merchantec”.

P 1829, L 13: Please add information about the used standard, to which international reference material it is calibrated, and that the values are given to VPDB.

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P 1829, L 19-21: Please rework the cave temperature description. Please give the month and °C of the maximum and the minimum and describe the trend between these extremes. Therefore, it will be consistent with Table 3.

P 1829, L 22: Please delete "(Fig. 2b)" in this line, because the average is not seen in this figure.

P 1829, L 24-25: Please add some information about the seasonality of the drip site. Also here the questions from before arise. Is it one or more drip sites, which were averaged, or is it water flowing along the surface of the flowstone? Please categorise your drip site/sites after the classification of Smart and Friederich (1987) and Baker et al. (1997). This makes the comparison with other studies much easier.

P 1830, L 4: Please make a new paragraph at the end of the sentence.

P 1830, L 7-8: The pH value is not related to the drip rate. Due to your measurement in the water pool on the flow stone surface the pH value is altered and not the initial one. It is much more related to the CO<sub>2</sub> in the cave atmosphere. There are a lot of studies describing this. Please, go into the literature and clarify this.

P 1830, L 11: Please replace "opposite trend" with "anticorrelation".

P 1830, L 15-18: The comparison of the two measuring methods of  $\delta^{13}\text{C}_{\text{DIC}}$  is not necessary for this paper. It could be perhaps a small study by its own, but it is not fitting in the interpretation of the monitoring data and the speleothem.

P 1830, L 21-28: This is all interpretation and not only results. Please move this to the discussion part.

P 1831, L 17 and 23: Instead of "contrasting behaviour" and "opposite trend" you could describe this as an anticorrelation pattern.

P 1832, L 3-21: Please reduce this discussion to the interpretation of the snow event. See general comment in relation to over interpretation.

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P 1832, L 26: Please add at the end of the sentence "(Fig. 3e)".

P 1832, L 22 to 1833, and L 3: Please rework this passage. Write that the drip water signal is quite constant, and the only noticeable thing is the negative peak in July/August. Say that it is in the range of the uncertainty, but that it is probably related to the strong decrease in the isotopic composition of the rain water in March. Do not make this passage longer than necessary.

P 1833, L 4-15: The residence time of the water is probably much longer than 6 month, because the  $\delta^{18}\text{O}$  signal in the drip water is really constant. To verify the exact time a dating of the water with tritium could give some more information. There is no doubt about that a portion of water reaches the cave after six month. Otherwise the decrease in the  $\delta^{18}\text{O}$  drip water data will not appear, but is very well mixed with water staying much longer in the epikarst.

P 1833, L 18: Please replace "evolution" with "cycle".

P 1833, L 21: You say that the temperature difference between cave air and drip water is also made in other cave, but possible reasons for this are not given here. Please add some information.

P 1833, L 22-23: The river could play a role in cave ventilation, but the biggest influence should have the number and altitudinal location of the entrances of the cave.

P 1834, L 17-18: Please be very careful with such a statement. Your measured pH is highly altered and is also highly dependent on the CO<sub>2</sub> concentration of the cave air.

P 1834, L 21: The water in the epikarst is not more acidic, due to a pH value above 7. Further, the water in the epikarst could be completely saturated with calcium carbonate and have therefore a pH of for example 8. Please discuss the issue of prior calcite precipitation, which could have an important influence on the pH values of the drip water.

P 1834, L 25: The delay of half a year is unlikely. It is much more likely that it is one

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and a half year or two and an half year.

P 1834, L 26-27: The pH value has nothing to do with the amount of dissolved ions. To say something about the ion content of the drip water you have to measure the elements and/or the conductivity. Therefore, please correct this sentence.

P 1834, L 27-28: This statement is not correct. One important factor for the precipitation of calcite is the saturation index. Further, the CO<sub>2</sub> concentration of the cave air plays a role.

P 1835, L16-17: Also during short residence times in the epikarst the water get saturated with calcium carbonate quite fast and the pH is altered when the water reaches the cave or when prior calcite precipitation takes place in the epikarst zone.

P 1835, L 23: Lachniet (2009) is not the best reference for this. There are several studies about the physics of calcite precipitation in cave environments.

P 1835, L 25: Please replace "kinetic effects" with "disequilibrium effects", because disequilibrium encloses all possible effects.

P 1835, L 26: Please replace "transfer-function" with "system".

P 1836, L 4-5: Please replace "the calcite-water fractionation factor" with "a calcite-water fractionation factor".

P 1836, L 7 and L 8: Please replace "in-lab" with "laboratory".

P 1836, L 12: Please replace "category of" with "approach to determine".

P 1836, L 19-29 and P 1837, L 1-2: Please delete "suggesting that it is deposited close to equilibrium with the drip water" in line 19-20, because 1‰ offset means that it is not in exact equilibrium. Depending on the fractionation factor it is more or less close to equilibrium. It should also be discussed that the best fitting fractionation factor of Tremaine et al. (2011) is a fractionation factor from the natural system and that it is questionable if real equilibrium could exist in nature. Please clarify these sentences.

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P 1837, L 3-4: Please replace "deposition of calcite occurs in oxygen isotopic equilibrium" with "deposition of calcite occurs near to oxygen isotopic equilibrium".

P 1837, L 12, 13 and 18: What do you mean with "fresh calcite", please clarify this.

P 1837, L 17: The aspect of drip rate influencing the  $\delta^{18}\text{O}$  of the calcite is not mentioned here. Please also discuss this point here.

P 1837, L 19-20: Please replace " $\delta^{18}\text{O}$  composition of the glass slaps" with " $\delta^{18}\text{O}$  composition of the calcite on the glass slaps".

P 1837, L 24-25: Please discuss the possible disequilibrium effects (e.g., evaporation) here in much more detail and why they did not play a role.

P 1837, L 27-28: Please delete "reflecting the C3 type vegetation growing above the cave", because this is not a thing which is clearly visible in a calcite composition of -10‰ of  $\delta^{13}\text{C}$ .

P 1838, L 3-6: There are much more factors in the cave environment influencing the  $\delta^{13}\text{C}$  composition of the calcite (e.g., drip rate, CO<sub>2</sub> of the cave air). Please give more information.

P 1838, L 13: You gave the number "1.001" here, but it is not clear what it is at that point  $\delta^{18}\text{O}$  or  $\delta^{13}\text{C}$ ?

P 1838, L 14-15: Here you gave a formula for  $\delta^{13}\text{C}$ . Please make it consistent.

P 1838, L 19-24: Please think carefully about the term equilibrium at this point. It is depending on the used fractionation factor (Mook or Romanek) and the other question is if really isotopic equilibrium fractionation could appear in a natural system. Also the fractionation in winter of  $1.4 \pm 0.5\text{‰}$  does not show real equilibrium conditions.

P 1838, L 28-29: Please be careful with such a statement. For this you should know the amount of CO<sub>2</sub> in the drip water, which could be calculated with the programme PHREEQC.

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P 1839, L 12-17: Please specify the temperature influence on the  $\delta^{13}\text{C}$  system. Please give some numbers as you did for the  $\delta^{18}\text{O}$  system.

P 1839, L 26-28: Please delete the term “kinetic evaporation” this is wrong in the context of  $\text{CO}_2$ . See also general comment to this topic. Further you be contradictory. First you say “kinetic” and in the next sentence “equilibrium” for the same issue. Please rework this.

P 1839, L 28-29: Wherefrom do you know that the cave air is dryer in summer? You did not show cave air humidity data. Please rework this! Show humidity data or delete this statement.

P 1840, L 2-3: Please calculate a correlation coefficient between  $\delta^{13}\text{C}$  from the calcite and the drip rate.

P 1840, L 5: It is Riechelmann et al. (2013) instead of (2011).

P 1840, L 10-11: “It is however not visible in the  $\delta^{13}\text{C}$  record of the DIC (Fig. 2i), which is at its lowest value than.” This is contradictory.

P 1840, L 13: Please replace “Heavier” with “Higher”.

P 1840, L 14-15: In relation to “evaporation” see comments above.

P 1840, L 18-20: Small or elongated crystals are not visible in Figure 4. Did you make thin section analyses of the crystals? Please clarify this. If you made some microscopy analyses please verify what an elongated crystal is and what a small crystal is. Please read Frisia and Borsato (2010) in relation to this topic. To my knowledge the crystal often do not “care” if it is a summer or a winter layer, they grew continuously over several layers. The difference of the crystals between summer and winter are more or less inclusions and in growth direction elongated holes. More inclusions and holes mean a faster calcite precipitation and therefore, a faster growth rate. Please clarify this.

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P 1840, L 25-27: How is it confirmed that the layer couplets are annual and how is the age model established? Did you make some datings (Th/U or  $^{14}\text{C}$  bomb peak or crossdating with a dated sample from the same flowstone)? Please clarify this and give some more information.

P 1841, L 16-18: You wrote that the ion concentration in the drip water plays a role for calcite growth rate, but did not provide data for this (e.g., saturation index with respect to calcite). There are also other factors which could influence the growth rate of speleothems (e.g., drip rate,  $\text{CO}_2$  concentration in the cave atmosphere). Please go to the corresponding literature and discuss this in more detail here.

P 1842, L 1-2: The absolute color contrast could be verified by measuring the gray scale of the layers. There are several programs available for this. When you could not measure this, please relativize this statement. Further the picture in Figure 5 is diffuse and the layers are not very well visible. Please put a better picture in Figure 5.

P 1844, L 3: Please replace “withe” with “white”.

P 1849, Table 1: Please replace “delta C” with “ $\delta^{13}\text{C}$ ” in the table caption. I think this method test is not necessary in this study, because it is beyond the scope of this manuscript and would be better put in a method paper.

P 1850, Table 2: It would be easier for the reader, when there are  $\delta$  listed instead of  $1000 \times \ln \delta$ , because the most readers are more in the “‰ world” that calculating with  $\delta$ .

P 1851, Table 3: Please replace “in equilibrium its drip water” with “in equilibrium with its drip water” in the table caption. Please change “d $^{18}\text{O}$ ” in the Table to “ $\delta^{18}\text{O}$ ”. Why is there an error given for the results from the fractionation factor of Tremaine et al. (2011)? Where does it come from and why all the others do not have errors?

P 1852, Fig.1: The font in the cross section is too small. Please enlarge it.

P 1853, Fig. 2: There are no figure captions given for a), b), d), f), g) and h). Please

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add these. Further the font in the figure is too small, please enlarge it. c) & d): Please replace “Cave T (°C)” with “T (°C)”, because you also give drip water temperature. Sometimes you write “Cave air” but also “Drip water” please unitizes this. g): Please replace “pCO<sub>2</sub> (ppm)” with “p CO<sub>2</sub> (ppmv)”. h), i), j), k), l) and m): For all axes “(‰ VPDB)” or “(‰ VSMOW)” are missing. Please add these.

P 1854, Fig. 3: This is not an appropriate figure caption. Please give figure captions for a), b), c), d), e) and f). c), d), e) and f): For all axes “(‰ VSMOW)” is missing. Please add these.

P 1855, Fig. 4: The picture could be a bit defined.

P 1856, Fig. 5: The picture should be much more defined to see the different layers. Further, “(‰ VPDB)” is missing for both isotope axes. Please add these.

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Interactive comment on Clim. Past Discuss., 10, 1821, 2014.