

General Comments

In this work, Vansteenberghe and co-authors present growth, morphology, and carbon and oxygen records from a single Belgian speleothem. The authors created an age model using U-Th dates and then compared the data to Greenland ice-core records and European speleothem records. Speleothem studies from northern Europe are sparse; hence, the study has the potential to fill an important gap in the spatial coverage of speleothem records, and to make an important contribution to our understanding of northwest European paleoclimate during the last interglacial and glacial inception. The interpretation and reliability of the results is slightly limited by the analysis of only one speleothem, however, I appreciate that caves are not well decorated in Belgium and to harvest the few speleothems that remain in the hope of finding a replicate would be unethical. The manuscript fits within the scope of CP.

Overall, I support the publication of the work after some substantial revisions have been made. First of all, there are many technical issues associated with the use of language and in-house publication standards, but these can be easily rectified. More importantly, the approach taken towards some aspects of the age modelling needs further explanation, and the interpretation of the mechanisms controlling the $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ signals is unclear.

Specific Comments

Line 16 - the larger European spatial coverage of last interglacial climate records does not need to come specifically from speleothems, consider revising.

Line 20 – Just because speleothems growing before 125.3 ka haven't been found yet, doesn't mean that they don't exist. Consider revising the bit about "speleothem formation starting relatively late in Belgium".

Line 30 – Greenland stadials are not recognized in the Belgian speleothem, rathermore, stadials occurred in Belgium that appear to be analogous to those in Greenland.

Line 31 – The last sentence needs revising. The second half related to Greenland Stadial 24 is fine, but the first half related to Greenland Stadial 25 is confusing. It is not clear that the Han-9 data is being referred to.

The first sentence of the introduction doesn't read well and needs revising. The higher temperature during the last interglacial also needs a reference.

Line 49 – the relationship between the two papers cited in this sentence is unclear.

Line 51 – I'm not sure that amelioration is the right word to use here

Line 59 – the orbital parameters were different to what?

Line 62 – D/O cycles don't control climate variability, they are a feature of it.

Lines 63-66 – Perhaps alternating would be a better word than succession? Nevertheless, the sentence needs revising. Atlantic Cold Events don't relate to the whole D/O cycle, plus the Atlantic Cold Events need a reference.

Line 70 – gradual cooling of what?

Line 95 – move the specifics about the length of the stalagmite to the cave setting. Then give more details about the sampling site. Average diameter? In situ or ex situ? Broken or complete? Refer to Fig 2C.

Line 108 – the rainfall is spread evenly throughout the year? Where does it come from? The same source all year? What is the modern $\delta^{18}\text{O}$ of the rainfall?

Line 114 – natural connection with which other parts of the cave? Perhaps indicate the underwater parts on the cave survey.

Line 113-114. Rephrase. The sample can't have been collected in the Réseau Sud OR the southern network of Han-sur-Lesse

Line 115 – mark where the tunnel is on Fig. 1B.

It would be helpful to mark the position of Réseau Rénversé, Réseau Sud, Gouffre de Belveaux, Trou de Han on Fig. 1B

The information about where the cave floods is confusing. Does flooding affect the sampling site?

Line 120 – when did the temperature logging take place? What were the sampling intervals?

Line 121 – why does the cave temperature reflect the average temperature for 2013, rather than the 1999-2013 average? Does this have implications for the interpretation later on?

The important point here is that the sample comes from the part of the cave with the stable temperature. Was that likely the same in the past? Or is there evidence for other entrances in the past that may have affected ventilation in this part of the cave?

Line 137 – normally the half-lives are given as part of the U-Th data table. If you wish to give them in the text, why only give ^{230}Th and ^{234}U , and not the half-lives for the other relevant isotopes?

Line 138 – specify atomic or activity ratio

Line 139 – And also Shen et al., *Geochimica et Cosmochimica Acta* 99 (2012) 71–86

What is the age datum?

Where were the stable isotopes measured?

Line 144 - 300 μm diameter, radius, length?

Line 145 – Revise sentence beginning “In function of the growth rate...”. It is unclear what is meant.

Line 146 - why were samples kept at 50°C

Line 149 – what is the in-house standard made from?

Line 153 - do you mean replicate sample?

Line 154 – how are outliers defined?

Line 163 – it looks like the detrital material is on the base and not just the sides.

Line 163 onwards - it would help to be more specific about the sections of the speleothem being discussed. E.g. layering is visible between 365-700 mm dft.

How are the discontinuities identified? Macroscopically? By ages?

Line 174 - ...dashed lines in figure 2D....

Line 174 – do you mean no macroscopically visible internal layering is present?

Lines 178-181 – You say that the latter fabric (i.e. the coarser one) has smaller columnar calcite crystals, thus you describe it as “columnar open”. You then contradict yourself and say that the “coarser morphology has substantially larger crystals.....defined as columnar elongated”.

Line 183 – How can the smaller more equant calcite crystals also cover the fine layer of brown detrital material that is D2.

Later in section 5 there should be some discussion about why the morphology changes throughout the stalagmite. Why does the fabric change from dense to coarse? Why is there visible layering in some parts and not others. What might cause the growth axis to shift for 20mm?

Line 187 – The datum is given here as 2015 CE. Yet in the table it is 1950 AD.

Include some text in section 4.2 about the concentration and cleanliness of the samples.

Line 197 – be more specific about the section of stalagmite

Do you have any idea why there are age inversions?

Line 198 - What are the distinctive changes in morphology?

Line 199 – I think there should be some mention that the best test for isotopic equilibrium is to have a reproducible record (see Dorale and Liu, 2009). However, in the absence of a second speleothem, the Hendy test has been used instead. Do any of the modern monitoring studies record calcite deposition in isotopic equilibrium with the drip water?

Age model – why does the oldest part of the age model (figure 5) appear to miss out sample DAT-1? It is within stratigraphic order, yet the age model appears to completely miss it.

Lines 218-223 – Why does the age model need to be adjusted at the end of growth phase 2? Looking at the ages in table 1, DAT 6, 16 and 19 are all in stratigraphic order within the limits of dating uncertainty. Why then is there a discussion about whether DAT-19 is an outlier or not? Why has linear interpolation been applied at the end of growth phase 2? For this discussion, the names of the relevant samples should be added to figure 5.

Incidentally, it would be helpful to mark on one of the figures, either figure 2 or figure 5, what is meant by growth phases 1,2 and 3.

Lines 224-232 – Refer to figure 5 for the timing of growth phases. Where is the growth rate data plotted? What is the reason for the change in growth rate? What is the temporal range of the stable isotope sampling interval (i.e., not just the average).

Line 235 – what is the reason for difference in $\delta^{13}\text{C}$ between modern and Han-9?

Lines 236-258 – This section on d13C needs some revision. The shift of 5‰ **to enriched values** in Han-9 is centred on c. 110 ka. How long does this isotopic excursion last for? Be more specific about when the grass assemblage at Eifel was at 40%. How reliable is the chronology on the maar lake record? After much discussion about the different factors that control d13C in speleothems, there is no decision as to which mechanism(s) are controlling d13C in this particular record. The end of section 5.2 concludes by saying that shifts in d13C are caused by changes in vegetation type. After assessing all the different causes of changes in d13C, why has this conclusion been reached? i.e., Why is prior calcite precipitation discarded? Furthermore, why is there a mismatch between the pollen record from Eifel and the d13C of Han-9 if changing vegetation is the control on d13C? Between c.126-114 ka broad leaf trees dominate the assemblage, hence one would expect a speleothem d13C of -6 to -14 ‰, and this is the case at c.-7‰. The enrichment in speleothem d13C is then in agreement with the decline in broad leaf trees and increase in grass assemblages. This is fine too. But then the speleothem d13C shifts to c. -9 ‰ after 109 ka, i.e. it is even more depleted than it was between 126-114 ka, yet at this time grasses are most abundant (60%) and trees much less (40%). If the shifts in speleothem d13C are really reflecting changes in vegetation, then the absolute d13C values and pollen assemblages from the maar lake are not in agreement.

Line 260 – “precipitation” is a bit vague in terms of control on d18O. Perhaps use moisture source, amount effect.

Lines 272-273 – “precipitation controls” is too vague. Do you mean amount? Is the North Atlantic Ocean the source for the precipitation all year round? And would it have been the source in the past?

Line 276 – global d18O values of what?

Lines 283-288 – be more specific about which sections of the d13C signal are controlled by the different mechanisms.

Lines 296-297 – The results presented here show quite clearly that speleothem deposition is not restricted to optimum interglacial conditions.

Lines 316-317 – Be specific about why this demonstrates that interglacial conditions were already present at 125.3 ka.

Line 321 – refer to figure at end of first sentence

Line 324-326 – revise sentence so that the time period that is being referred to is clear

Line 329 – refer to figure 7 at end of list about speleothems and ice cores

Line 331 – reference for enhanced Greenland melting

Line 332 – you say there is a constant growth rate, but there are only three data points through which the age model passes over nearly a 9 cm interval. I come back to the earlier comment that the age for DAT-1 is completely ignored by the age model, despite being in stratigraphic order. If the age model took this age into account, then the growth rate would not be constant over the interval 120-125 ka.

Line 333 – no significant change in what over time? What is it about the layered calcite that indicates a stable climate?

Line 336 – refer to figure at end of first sentence.

Line 336 – don't use "onwards", be specific about the time interval being discussed. This is important for the sentence where it is stated that no major changes in d13C are observed. Major changes take place at 117.5 ka (as is discussed in the next paragraph), and this is "onwards" of 120 ka.

Line 336-337 – This needs rewording. At 120 ka, there is indeed an enrichment in d18O of 0.5‰, and the growth rate does change at this point, but the reduction in diameter doesn't appear to happen until later within this growth period. Also refer to figure 2 regarding growth diameter.

Line 336-352 – In the results section there was a lot of text about the d18O being controlled predominantly by temperature, but in this section it has now switched to both amount and source effect. Also, why does it switch from amount to source?

Line 355 – the sentence beginning "As the increase...." isn't complete. It is only the first part of a thought. What is happening as a result of the increase in d13C?

Line 358-361 – yes the beginning of the hiatus takes place within GS 26, but the age 117.3 ka doesn't stand out as a particular event within Greenland. GS-26 began at 119.1 ka (Rasmussen et al., 2014)

Line 370-371 – add the Meyer et al 2008 data to figure 7.

Hiatus 1 – boreal forests recover after the LEAP event, but the speleothem doesn't start growing until much later. Please comment.

Line 390 – use the GICC05modelext timescale rather than GICC05

Line 389 – in Rasmussen et al 2014, GS 25 is 110.6 to 108.3 ka

Line 396 – there is a different timing here for GS25 compared to line 389

Line 396 – suggesting what is mainly temperature controlled?

Line 400-401- Rephrase the question. You ask why speleothem growth continued during GS 25, but then answer why it stopped during GS24.

Line 404 – Growth rate decreased at the same time d18O increased (amount effect=less rainfall), but d13C decreased

Line 411-412- weak ending. Yes the age model is poorly constrained, but the ages clearly cluster within the interval 97-103.6 ka, hence, the more depleted d13C appears to be in good agreement with the high abundance of grasses. Perhaps it is a problem with the Eifel Maar chronology, rather than the U-Th chronology? You should discuss whether PCP or fractionation effects might be responsible.

Technical corrections

General comments – There are many issues related to grammar, use of articles, prepositions, language, and in-house standards. Please address them.

Line 12, 13, 16, 20, keywords, 37, 42, 85, 350, – “Last interglacial” is not a formal geological subdivision and hence should not be capitalized. See guidelines for authors. http://www.climate-of-the-past.net/for_authors/manuscript_preparation.html

Line 17, 91, 98, 99, 106, 113, 114, 125, 251, 265, 278294, 374 – Hans-sur Lesse Cave (author guidelines, Capitalize generic geographic terms, such as "river", when they are part of a place name,)

Line 18 - remove “The” before Han-9

Line 22 – ...time; therefore, it ... or ...time. Therefore, it ...

Line 24 - ...ka, however, at

Line 26 - define MIS

Line 28 - ...that the climate ...

Title, line 29, 46, 48, 79,82, 97, 381, 415, 422, 429, 433, – again Early Weichselian is not a formal subdivision, it should be “early Weichselian”

Line 30 – “Greenland stadials” (lowercase)

Line 31 – ... are recognized in Han-9 and the ...

Line 35 – Keywords. millennial-scale variability, Greenland stadials

Line 37, 60, 62 – last glacial (lowercase)

Line 39 – provide abbreviation after Marine Isotope Stage

Line 42/43 - ...about the LIG nomenclature...

Line 50 – Eem River valley

“Capitalize generic geographic terms, such as "river", when they are part of a place name, but do not capitalize the generic term when it appears on its own, when it follows a capitalized generic term, or when it is in the plural (e.g. Mississippi River, Mississippi River basin, Mississippi and Missouri rivers).” http://www.climate-of-the-past.net/for_authors/manuscript_preparation.html

Line 52 –vegetation to today.

Line 53 –of up to 20 ka...

Line 57 - ...LIG has gained...

Line 60 - ...Revise sentence beginning “Subsequent to the Eemian”.

Line 60, 62 – lowercase “last glacial”

Line 62 – millennial-scale

Line 64 – ...Greenland stadial (GS) and interstadial (GIS) phases....

Line 65 -Atlantic cold events.....

Line 66 – lowercase stadials

Line 66 – lowercase ice-rafted debris (IRD)

Line 67 – North Atlantic Ocean

Line 75 –lowercase interglacial

Line 76 – late Quaternary

Line 76 -78 – Revise grammar and prepositions

Line 92 – ...and demonstrated that...

Line 95 – 70cm long (Under the author guidelines, there is no space between the number and the unit)

Line 100 - ~10km

Line 104 - ...consisting of middle to late Givetian reefal....

Line 104, 111, 115, – Lesse River (author guidelines, capitalize river when part of a name)

Line 105 – (Fig. 1B)

Line 105 – 40m.

Line 106 – 200km and 200m

Line 106 – define a.s.l.

Line 106 – why swap from ~ to ca.

Line 108 – 10.2°C

Line 109 - ...consists of C3...

Line 110 – Quercus trees, and

Line 112 – the sample has a different name

Line 120 – Short-term temperature...

Lines 121, 122, 124, 135 – remove space between number and unit

Line 136 – remove italics

Line 136 – it was already stated that the analyses were carried out at the University of Minnesota

Line 136 – define MC-ICP-MS

Line 142, 145, 147, 148, 149, 153 – remove italics

Line 143 – ...growth axis to avoid...

Line 151 – define VPDB

Line 160 – Figures 2C-2E

Line 160 – of Han-9.

Line 161 – replace up to 365mm dft, with below 365mm dft

Line 161 – rephrase “extremely good expressed”

Line 161-162- ...and consists of alternating sub-millimeter sized layers of white and slightly darker calcite.

Line 162 – Replace “At the very base “ with something like “In the lower 10mm,...

Line 171 – Be more specific about the upper part. Perhaps, “Following D2, the axis of growth for the next 20mm is tilted to the right”.

Line 176 –calcite (Fig 2E), where.... andinclusions (Fig. 3B), and thereby described....

Line 189 – 666 and 212 years are the wrong way round

Line 194. Figures

Line 196 - ... values show smaller....

Line 207 – Figs.

Line 213 - ...it is correct to assume....

Line 216, 217 – spell three

Lines 224-232 –Remove spaces between numbers and units (see author guidelines). Revise text so that it is in the past tense, i.e., “The first and oldest growth phase started at 125.34”

Using both first and oldest is unnecessary, one of them is redundant

Line 225 – After that, the growth....

Line 228 – As for growth phase 2, the growth....

Line 231 – comma instead of period in 97.22

Line 236 - ...changes of up to....

Line 241 - ...indicate that grass-like C4 pollen increased up to 40% of the total assembly between 106 and 98 ka. (At the moment it is unclear which part of the 130-110 ka relates to the 40% grass assemblage)

Line 246 – Revise grammar in sentence about Genty, 2003.

Line 248 – ... more specifically less

Line 249 – The isotopically heavier...

Line 249 – ...an increase in $\delta^{13}\text{C}$ of

Line 256 – change were to where

Line 257 – 100ppm

Line 260 - ...of changing climate expression...

Paragraph beginning In the mid-latitude – check for spaces between numerals and units

Line 270 - ...via the amount effect...

Line 274 - ...covers an interglacial-glacial....

Line 275 – North Atlantic Ocean

Line 276 – global ice volume

Line 276 - Waelbroeck et al. (2002) estimated that...

Line 280 – plural ratios

Line 292- Revise first sentence.

Line 297 – Sentence beginning “Strongest melting....”, restructure

Line 300 – spelling of Moseley

Line 300 – refer to Fig 1a for alpine and southern Europe speleothem studies

Line 303 – ka missing after 115.3 +/- 0.6

Line 309 - ...as well, such as

Line 310- Rephrase “The 125 ka time”

Line 313 – define s.s.

Line 321 - ...records of Han-9 are...

Line 322 - ...confined to between...

Line 324 – insert ka with dates

Line 324 -are made for $\delta^{13}\text{C}$: sub-

Line 347 –more regional signal,....

Line 351 - ...towards an MIS 5d....

Line 352 – insert ka after ages

Line 364 – define NADW

Line 364 - ...observed during MIS 5e.

Line 366 - ...cooling of the climate.

Line 374 - spelling Moseley

Line 375 - ...an increase in varve thickness

Line 386 - ...curve of Han-9 shows a long-term increasing trend to a maximum of -4‰ at 110ka.

Line 387 -within the d18O record a long-term...

Line 394 – sea surface temperature (lowercase)

Line 396 – in Han-9

Lines 410 – tends toward

Line 419 – recorded in Han-9

Line 420 – The first signs

Line 430 – add ka to ages

Line 434 – amplitude and frequency of isotopic shifts

Figure 1 – spelling Moseley

Figure 1 – The sampling site of Han-9

Figure 2 – d18O plotted against distance from top in mm

Figure 5 – what is the error? The 95% confidence limit?

Figure 6 – spell two

Figure 7 – add Meyer et al., 2008. Use GICC05modelext timescale for Greenland. Separate F and G into d13C and d18O respectively. What are the horizontal lines on H?