

RC1: Anonymous Referee #1, 21 Aug 2024

Torner et al use a speleothem record from the Western Mediterranean region to provide new absolute age constraints to the glacial terminations of TIV, TIII and TIIa. They use speleothem proxy data to provide additional hydroclimatic context to these time periods. And provide extensive discussion on how this record can be used

- to evaluate orbital forcing on Terminations,
- to evaluate the differences between millennial structure of the different Terminations,
- to provide absolute age control to marine records through tie points
- and to provide a fuller picture of the sequence of climate events during Terminations.

It would be great to see this article published. I have only a few comments that would hopefully make it easier to garner more information from the article.

We sincerely appreciate your review of the article. We are pleased to know that you found it interesting enough to be considered for publication. We greatly value your observations and corrections, which will certainly improve the clarity of the manuscript. Below, we have addressed your comments.

Comments:

- In the introduction, please can you add just a sentence or so on why it is relevant to study Terminations in the context of current climate change

We will address this point after the first paragraph. We propose to add these sentences:

i.e Line 53: These feedbacks responsible for past deglacial warming can also play a role in the ongoing situation of climate change. The increase in atmospheric CO₂ due to anthropogenic emissions, the reduction in earth albedo resulting from ice melting, and even the weakening of the AMOC are currently in operation (IPCC, 2023; Boers, 2021). Studying past glacial terminations provides unique examples for elucidating the role that these internal components on Earth's climate system had during past periods of global climate warming, a test ground for better contextualizing current climate change.

Boers, N. Observation-based early-warning signals for a collapse of the Atlantic Meridional Overturning Circulation. *Nat. Clim. Chang.* **11**, 680–688 (2021). <https://doi.org/10.1038/s41558-021-01097-4>.

IPCC, 2023: *Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, H. Lee and J. Romero (eds.). IPCC, Geneva, Switzerland, 184 pp., doi: 10.59327/IPCC/AR6-9789291691647, 2023.

- Lines 65-70: It would be great if any speleothem could truly have an unambiguous climatic interpretation! It would be better to phrase this as 'relatively unambiguous climate interpretation' or 'better understood climate interpretation'.

This is indeed a valuable consideration. Is true that there is no unambiguous interpretation of speleothem proxies. We have been too enthusiastic in this sentence. We appreciate your observation and will change the sentence for 'relatively unambiguous climate interpretation' as you suggested.

- Lines 105-110: Sub-heading 2.1 should be more appropriately named as maybe 'cave setting and regional hydroclimate' or so. All the cave description could come first followed by a description of regional hydroclimate. So the sentences at Line 122, 'The Murada cave....' Onward should move to the start of that section.

Thank you for your suggestion. We will implement this change and use 'Cave Settings and Regional Hydroclimate' as the sub-heading title. Additionally, as also recommended by Anonymous Referee 2, we will revise the structure of this section. Specifically, we will move the cave setting information to the beginning of the section and incorporate information from the other speleothem cave as well.

- Section sub-heading 2.2 should be Geochemical analyses.

We will correct that.

- Lines 140-145: Was the reversed age removed or included in the final age model generation by StalAge?

Of the 41 original samples, the age model was constructed using 39 samples. One of the excluded samples was a replicate used to evaluate consistency between different analysis dates, while the other was ignored because represented the most prominent reversal. Although the modeling process with StalAge considered all 39 samples, the final age model placed several dates at the limit of the model, with some exceeding the model's dating uncertainty. To clarify this, we will write 'with a few single dates exceeding the final modeled dating uncertainty' instead of 'with only a single reversal exceeding the dating uncertainty'. Furthermore, we will add visual support in Fig. 2 (attached at the end of the document)

Finally, this paragraph will be as follows, including also VALL 2 information:

i.e., Line 140-145: The speleothem depth-age models were performed with the R software and the StalAge package (Scholz, 2011), using 39 radiometric dates for RAT and 12 for VALL 2. The RAT speleothem provided a consistent chronology with a few single dates exceeding the final modeled dating uncertainty. It presents a remarkably precise age model for this period, with absolute uncertainties being even smaller in the youngest part of the speleothem (Fig. 2). The dates obtained

from the VALL 2 speleothem are approaching the limits of the U-series dating technique, thereby resulting in significant uncertainties, being even larger in the oldest section of the speleothem, where the growth rate is higher (Fig. C1). The growth rate ranges between 0.02-1.2 cm/kyr for VALL 2 and 0.07-1.7 cm/kyr for RAT.

- Lines 140-145: Add MIS and Termination numbers to this figure to make it easier to understand the text around Lines 190. Please can you also show the exact sample points as markers either in this figure or in the appendix. It would be good to see how many samples cover the slow growth periods.

Yes, we have changed this figure and incorporated your suggestions. The modified figure can be found at the end of this document.

- Lines 150-155: 'Concurrently measured' should instead be 'made on aliquots of the same powder sample'. Also remove the word estimated since these are simply results that have been measured and compared.

Yes, we will change both sentences as follows:

Stable isotopes and trace elements have been measured on aliquots of the same powder sample in both speleothems. The $\delta^{18}\text{O}$, $\delta^{13}\text{C}$, and Mg/Ca ratios have been compared in detail to evaluate their paleoclimatic signals.

- Lines 165-170: What is CCiT-UB?

The CCiT-UB is the acronym for the Scientific and Technological Centres of the University of Barcelona. This abbreviation was mentioned a few lines earlier (line 158), and for that reason, we are directly using the acronym here.

- Lines 265-270: Since so much of the discussion surrounds the sequence and duration of events, it would be great to have an idea of the uncertainties of these records, i.e. not just the speleothem record produced in this study, but also the other records being discussed in this figure. If the data are available, these could be plotted in the figure, if not, some estimates as a table or in the text would be great. Similarly, it would be good to see in the figure or have it noted in the text, if any event is represented by a single sample measurement. And the same for Figures 4 and 5.

You are absolutely correct in the necessity to clarify the uncertainties related to the data exposed. At the top of Figure 3, there are the dates with errors from Corchia and Ejulve records. Now, we also added dates with errors from the Sanbao cave record. The errors associated with the Tenagi Philippon record are not published, but they assume one kyr lag with the orbital parameters. To have a more comprehensive discussion we decided to add some additional information in the text too:

i.e. (line 267): Other speleothem records from the Austrian Alps and Sardinia also reflect warming or more humid conditions along the MIS 7e responding to changes in the North Atlantic realm (Spötl *et al.*, 2008; Columbu *et al.*, 2019; Wendt *et al.*, 2020). Considering that the typical dating error along the MIS 7e of the RAT record averages ~1.2 kyr, the discussed records present similar values, Sardinia (1.5 kyr) and Ejulve (average of 2 kyr). While the record from the Austrian Alps record reached exceptionally reduced errors of 0.3 kyr.

i.e. (line 282): The Tenaghi Philippon age model relies on orbital tuning, assuming a constant lag of one thousand years in the orbital alignment, a circumstance that may account for certain discrepancies with the absolutely dated speleothem record. Aside from the age biases during deglaciations, both records exhibit proxy fluctuations associated with glacial/interglacial cycles as well as stadial/interstadial structures with a strong precession signal.

Furthermore, in Figure 2 we add all the sample positions as symbols in the three proxy records to clarify that any of the further discussed events is represented by a single sample measurement. Additionally, a sentence will be added to provide further clarification:

i.e. Line 156: Samples are spaced every 0.5 mm during glacial terminations to increase temporal resolution due to low growth rates, ensuring that events are captured by more than one measurement.

- There are some typos in the text so it could do with another check.

Thank you. We will do an additional check for typos and spelling.

Figure 2

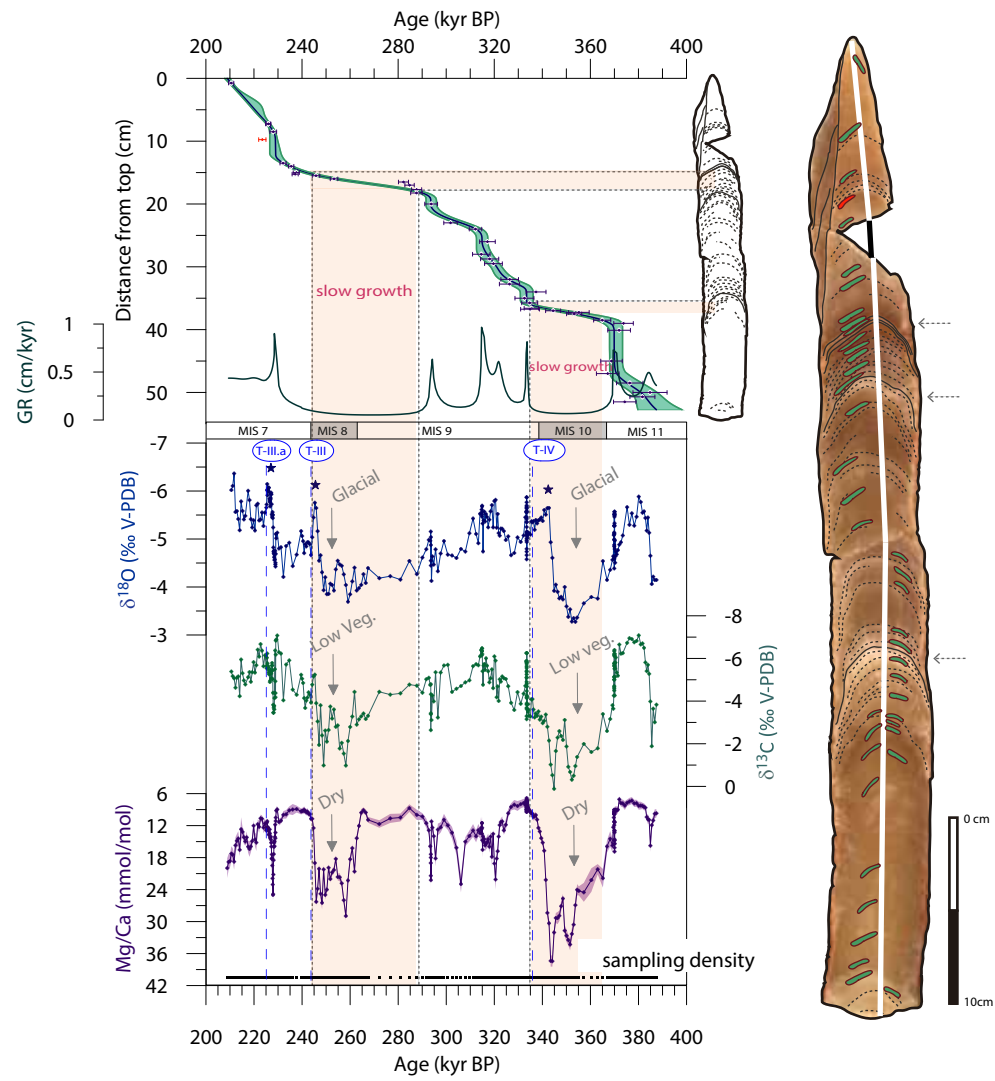


Figure 3

