

Interactive comment on “NALPS19: Sub-orbital scale climate variability recorded in Northern Alpine speleothems during the last glacial period” by Gina E. Moseley et al.

Anonymous Referee #2

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General comments: Moseley et al. present an updated version of the northern Alps speleothem $\delta^{18}\text{O}$ record for the last glacial (NALPS19). Earlier versions of this record have provided crucial information for the interpretation of the timing and expression of sub-orbital glacial climate change in central Western Europe and their close connection to Greenland. Moreover, given the possibility to obtain high-precision U-Th ages from stalagmites, these records have the potential to help refine crucial, but so far debated, portions of the Greenland ice core record chronology. With the new NALPS19 record, the authors significantly increase the temporal coverage of the record during the last glacial, and improve previous versions of the record using more precisely dated stalagmites. This allows them to compare the NALPS19 chronology with different Greenland

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ice core chronologies, with the potential to refine the latter. This is for example the case for the duration of the period from GS-22 to GI-21.2, for which the authors propose a new duration based on the speleothem record. Moreover, the authors discuss variability and influencing processes on speleothem $\delta^{18}\text{O}$ in their record, and possible biases in some locations, although they acknowledge that these interpretations remain often preliminary and will require a more dense dataset, possibly coupled to model simulations. Finally, the authors also discuss the presence of centennial-scale “precursor” events, which are present in both Greenland ice core records and the NALPS19 speleothems, and which they interpret to be related to meltwater pulses accompanying stadial-interstadial transitions.

Overall, this study is of importance to the broader palaeoclimate community, as it provides a significant advance in the coverage of the last glacial in the Alpine region, and is therefore within the scope of Climate of the Past. The study is well-designed and provides new data that allows substantial conclusions as to the close connection between Greenland and northern Alps during the last glacial, as well as firm geochronological anchoring points for some previously debated Greenland stadial/interstadial events. The methods used are well-described and valid, and overall the results support the interpretations.

My main point of critique is in the sometimes lengthy discussion, which can be difficult to follow for non-experts in both ice cores and speleothem science. I therefore suggest the authors provide moderate revisions (see specific and technical comments) to the manuscript before it can be accepted for publication.

Specific comments: Discussion of chronology (section 4.2): This section is in parts difficult to follow, especially for readers not overly familiar with the ice core literature. Some studies are cited, but the reasoning for this is not explained, and this can be confusing. I suggested some instances where some more background would be beneficial to improve overall clarity (see technical comments).

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This is especially the case for the discussion of GS-22. I think it would be worthwhile to restructure this paragraph and clarify the main message, i.e., NALPS19 allows to re-evaluate conflicting results from different ice core age modelling techniques, and this is especially clear for the interval between GS-22-GS-21.2.

Discussion of palaeoclimate and $\delta^{18}\text{O}$ (section 4.3): I am a bit confused with the treatment of the Siebenhengste record. At the beginning of the section, the authors exclude the LGM part of the record from Siebenhengste from their discussion on the range in $\delta^{18}\text{O}$, because of the influence from different moisture sources previously inferred for this time period. Here I was hoping the authors could provide some more background as to why this moisture source effect is only seen in the 7H LGM record: is it due to the time period covered or is the location of the cave the likely reason for this? Why are the authors certain that changes in moisture source were not an issue for any of the other records in the compilation? Further along in the text, there is a lengthy discussion of why the Siebenhengste record is anomalous, but there is no more mention of the source effect. I think it would greatly benefit the flow of the manuscript if the authors could elaborate a bit more on their reasoning for this, and link it back to the beginning of the section and the discussion on source changes during the LGM.

Discussion of stadial-level centennial-scale cold events (section 4.4): I think these events need to be more clearly pointed out in the figure 7, or even in a separate, zoomed-in figure, as it is not particularly clear what is meant now.

Technical comments: Page 1: - line 21: The meaning of AICC2012 needs to be specified, otherwise this sentence is very confusing for non-experts. - line 37: please add "oxygen" to "isotopic records" to clarify what is meant.

Page 2: - lines 31 and following: I think here the authors must clearly state that this chronological issue is also present in the ice cores and not only between the NALPS record and the ice cores.

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Page 3: - line 2: "controlling the $\delta^{18}\text{O}$ of precipitation in this region" would be more precise. - line 20: "the northern Alps receive" (instead of receives)

Page 4: The description of the sites and stalagmites is a bit lengthy and confusing in parts. I wonder if it would be better for the flow of the manuscript to summarise these details in a table, and streamline the text?

Page 5: Lines 28 and following throughout the sample description: U concentrations should be in ng/g (not ug/g) according to Table 2.

Page 6: For the caves with only one stalagmite analysed, it would be better to merge the two headings into one.

Page 8: Lines 27 and following: please add some context here regarding the chronologies GICC05modelext and AICC2012, otherwise it is difficult to follow for readers less familiar with ice cores.

Page 9: Lines 2-4: Please provide a brief explanation of what the findings of Extier are for the readers not familiar with this study.

Line 5: Please add the ages of the GS-22 interval here for context. Also, given that this is discussed at length over the next section, I would appreciate if the authors could point out this interval (and GI-GS21.2) in Fig. 3 or 5.

Lines 6-7: "Vallelonga et al. (2012) proposed the duration of GS-22 to be $2,894 \pm 198$ years and GI-21.2 - GS-21.2 to be 350 ± 19 years (together $3,244 \pm 199$ years, two sigma error)." This sentence reads confusingly to me: I assume the authors mean that the duration of the transition between GI-21.2 and GS-21.2 to be 350 years, while the entirety of the interval is 3244 years?

Line 9: NGRIP-EDML should be explained.

Page 10: Line 10: "The highest and lowest $\delta^{18}\text{O}$ values for stadials and interstadials also both come from the same caves." I find this sentence confusing: the highest and

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lowest in general? Which cave are these values from?

Line 27: I would rephrase “mean d18O” to “mean d18O of an entire record” or similar.

Line 35: “For a given location, however, Ambach et al. (1968) argued that the altitude effect cannot be the result of a difference in condensation temperature, because the condensation level should be approximately the same.” I find this sentence confusing, and would also appreciate some more details on why the condensation level is the same.

Page 13: Line 32-35: “Furthermore, we suggest that the highly-debated GS-22 - GI-21.2 - GS-21.2 interval had a duration of $3,857 \pm 249$ years, which is in closer agreement with the $4,121 \pm 325$ years of NGRIP-EDML (Capron et al., 2010b) and the $3,793 \pm 805$ years of the Asian monsoon composite (Kelly et al., 2006; Kelly, 2010; Cheng et al., 2016).” Closer agreement than what?

Figures: Figure 3: In the caption, I believe there is some information missing. For c) only the Dongge data is referenced, and there is no mention of Hulu. There is also a repetition at f) “for (e) colour-coded the same”. Figure 4: I think this figure would benefit from some additional work. For example, it would be clearer if the different ice cores (b) and stalagmites (c) for which the ramp-fitting was done were indicated in the figure with labels. Also, possibly adding labels for the transitions identified in the Greenland records would help. Figure 5: Here it would be helpful to the reader if the records were labelled, as in figure 2. Figure 6: I think it would be helpful to have a legend in the figure showing which symbol belongs to which cave.

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