

Moseley et al. would like to thank both reviewers for their insightful comments that provide excellent guidance for improving the manuscript. In summary, we agree with the majority of the comments and are happy to revise the manuscript accordingly.

## **Response to Reviewer 2**

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.

AC: Reviewer 1 made similar comments, hence the text will be revised accordingly.

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).

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 reevaluate conflicting results from different ice core age modelling techniques, and this is especially clear for the interval between GS-22-GS-21.2.

AC: Agreed, this will be revised accordingly.

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.

AC: This is incorrect. It is excluded on the basis of different transport pathways. Moisture source alone would be a different concept.

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?

AC: This is beyond the scope of this study. The LGM record is a paper already published and thus an in-depth discussion already belongs to the original study.

Why are the authors certain that changes in moisture source were not an issue for any of the other records in the compilation?

AC: Again, it is not a matter of moisture source but transport pathway. The reviewer is referred to the original paper for an explanation, but in short, the Siebenhengste record only records changes in transport pathway and associated Rossby wave breaking at the LGM and not for the remainder of the glacial. We therefore assume the same for the other records, and since we have none covering the LGM, this is not a problem for us.

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.

AC: As already mentioned, the changes at the LGM are specific to this time period. The ice sheets were not big enough in MIS 5 to cause the same changes to transport pathways as at the LGM. Even in early MIS 2, such changes were not apparent at Siebenhengste.

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.

AC: A zoomed-in figure can be added to the SI

Page 1: - line 21: The meaning of AICC2012 needs to be specified, otherwise this sentence is very confusing for non-experts.

AC: Agreed, this will be revised accordingly.

- line 37: please add “oxygen” to “isotopic records” to clarify what is meant.

AC: Agreed, this will be revised accordingly.

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.

AC: we do not mention it is between NALPS and ice cores, just that it is present in both chronologies

Page 3: - line 2: “controlling the d18O of precipitation in this region” would be more precise. –

AC: Agreed, this will be revised accordingly.

- line 20: “the northern Alps receive” (instead of receives)

AC: Agreed, this will be revised accordingly.

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?

AC: Agreed, this will be revised accordingly as per R1 also.

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

AC: Agreed, this will be revised accordingly.

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

AC: Agreed, this will be revised accordingly.

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.

AC: It is unclear what is meant by ‘context’. A review of ice core chronologies is beyond the scope of this manuscript.

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.

AC: Agreed, this will be revised accordingly.

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.

AC: Agreed, this will be revised accordingly.

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  $350 \pm 19$  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?

AC: Agreed, this will be revised accordingly.

Line 9: NGRIP-EDML should be explained.

AC: Agreed, this will be revised accordingly.

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

AC: Agreed, this will be revised accordingly.

Line 27: I would rephrase "mean  $d^{18}O$ " to "mean  $d^{18}O$  of an entire record" or similar.

AC: Agreed, this will be revised accordingly.

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.

AC: The sentence clearly starts with 'for a given location', therefore if it rains at a given location but at different altitudes, then the condensation occurred at the same point, because it is the same rain event.

Page 13: Line 32-35: "Furthermore, we suggest that the highly-debated GS-22 - GI21.2 - 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; 35 Kelly, 2010; Cheng et al., 2016)." Closer agreement than what?

AC: Agreed, this will be revised accordingly.

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. AC: This Hulu data is part of the Cheng et al 2016, but it could be more explicit. There is also a repetition at f) "for(e)colour-coded the same".

AC: Agreed, this will be revised accordingly.

Figure4: 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. AC: Agreed, this will be revised accordingly as per R1 also.

Figure 5: Here it would be helpful to the reader if the records were labelled, as in figure 2. AC: Agreed, this will be revised accordingly.

Figure 6: I think it would be helpful to have a legend in the figure showing which symbol belongs to which cave.

AC: Agreed, this will be revised accordingly.