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Interactive comment on "Precise timing of MIS 7 sub-stages from the Austrian Alps" *by* Kathleen A. Wendt et al.

Kathleen A. Wendt et al.

kathleen.wendt@uibk.ac.at

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We greatly appreciate the excellent insight provided by reviewer #1. Below is a list of individual comments and questions followed by our responses:

1. I am not very convinced of the data presented from the two new stalagmites, and I think the authors should consider the beneïňĄts of including them here.

We agree that our original manuscript lacked sufficient evidence to ensure that the two new stalagmites (SPA 146 and 183) were deposited close to isotopic equilibrium with dripwaters. To address this issue, we have re-sampled 8 Hendy tests from SPA146 and 5 from SPA183 (see new supplementary figures, attached). The results present a more comprehensive picture of the two stalagmites. The lack of statistically significant

covariation suggests that the isotope records of SPA 146 and SPA 183, like SPA 121, are not significantly affected by kinetic processes.

It's important to note that the stable isotope values from each stalagmite do not replicate each other perfectly – a feature commonly seen in speleothem studies elsewhere. This may be due to several factors (see responses below for a discussion on this topic). However, we argue that the isotopic trends generally agree and can be interpreted in relative terms as a proxy for past regional climate changes. To this end, we maintain that stalagmites SPA 146 and 183 provide valuable insight into the timing of and regional cooling at the onset of MIS 6.

2.- Source of precipitation. The authors indicate two main sources of precipitation in this region, which can be differentiated by the d18O isotopic values. I agree with this statement, but I consider that Atlantic sourced precipitation may not be much more negative than the Mediterranean one, depending on the moisture uptake along the longer pathway. Rainout effect is sometimes compensated by the more positive recycled moisture that is being incorporated in the way from the source to the Central Alps. It is then important to take into account the moisture recharge through the long pathway as, sometimes, the result is an enrichment derived by the effect of enriched inland moisture compared to ocean moisture. See, for example, Chakraborty et al., (2016) and Krklec and Domínguez-Villar (2014).

A discussion of precipitation d18O in the central Alps is provided on lines 57-62. On line 57 we cite a modern back-trajectory study. On line 60 we cite a study that examined the various processes that influence d18O signatures of modern precipitation in the central Alps.

A discussion of the d18O values of dripwaters in Spannagel cave is provided on lines 79-82. We cite studies that investigated the d18O signature of Spannagel dripwater and its comparison to local precipitation sourced from both Atlantic and Mediterranean regions. Overall, we believe that this combination of site-specific modern precipitation and dripwater calibration studies provides sufficient evidence to support our interpretation of Spannagel d18O.

3. Similarity with d18O monsoon records. The authors indicate several times in the discussion the high similarity with Asian monsoon records (lines 175, lines 235, etc); I think these statements should be modulated as I observe many differences in timing and pattern in Fig. 4. Both the similarities and the differences must be clearly described. For example, the time of TIIIa is completely different, also the pattern. The time of 7d as deïňĄned in Spanagel (234-216 ka) does not coincide at all with Chinese monsoon timing. Please indicate and explain potential mechanisms for those differences.

We agree that our original text lacked a full-picture explanation behind the interpreted similarities between the Chinese monsoon and Spannagel records. For example, we highlighted the similarities between variations in the Spannagel δ18O and Chinese Monsoon δ18O on sub-orbital timescales (e.g. line 175), but did not explain why the two locations are decoupled on other timescales (e.g. orbital) which may cause confusion to readers. We have now expanded our discussion of Spannagel δ18O vs Chinese Monsoon δ18O.

Regarding the timing of MIS 7d: we agree with the reviewer that Fig. 4 and its related text may render confusing without a clear reiteration of age uncertainties associated with both records. For example, the period of maximum isotopic depletion of MIS 7d calcite in Spannagel (229.2 ka) appears early, but is actually within the $\sim$1 ka age uncertainties of the Chinese Monsoon record (228.2 ka). Nevertheless, statements such as line 235: “Remarkable similarities in the shape and timing of maximum MIS 7d conditions between Chinese Monsoon and Spannagel δ18O provide clear evidence for abrupt cooling of the North Atlantic at this time” comes across too bold without an emphasis on the respective age uncertainties of each record. We have reworded these and similar statements to include a comparison of age uncertainties.

The end of MIS 7d is marked by the onset of TIIIa, which according to Cheng et al. 2016, occurs in the Chinese monsoon record at 217.1 $\pm$0.9 ka (see line 254). The timing of TIIIa is therefore well within uncertainties of both records. To further emphasize this, we have added brief explanation of the timing of TIIIa in the Chinese monsoon in the caption of Fig. 4.

- Line 26. I miss one or two references here to support this statement.

We added the citation PAGES (2016) as a summary reference for MIS 7 substages.

- Line 140. Replication just happens during very short periods of time, if any, and the values and trends are not so well reproduced. I would not use those criteria for discarding kinetic effects.

We have re-sampled multiple Hendy tests for SPA146 and 183 in order to provide a more robust test for possible kinetic effects (see response to first comment). It is true that the absolute d18O and d13C values from each stalagmite do not replicate each other perfectly. This may be due to several factors (see response below). However, we argue that the isotopic trends generally agree between stalagmites, particularly in their trend towards depleted values at the onset of MIS 6. Returning to the reviewers’ point, we no longer argue that replication is the main line of evidence against kinetic effects; instead, we point to the evidence provided by the new Hendy test analysis.

- Line 147. This just applies for SPA21, the other two stalagmites display more negative values. Please, explain why.

We argue that prior calcite precipitation (PCP) likely influenced the stable isotope values of SPA121. Two lines of evidence support this hypothesis. During cool periods, low d18O intervals recorded in SPA 121 coincide with very high d13C (e.g. during the MIS 7a-6 transition). During warm periods, second order features locally co-vary (see discussion section 4.3 in Spötl et al. 2008). These observations point to a kinetically controlled process, such as PCP. A second line of evidence is that SPA 121 grew very slowly relative to SPA 146 and 183, indicating a very slow drip rate (and thus, higher likelihood of PCP).

The results of PCP would lead to an overall enrichment in the absolute values of d18O and d13C recorded in SPA 121. The growth rate of SPA 121 is consistently slow; thus, one could argue that PCP was active throughout our time period of study. Assuming this, PCP alone cannot account for the shifts in stable isotope values observed during the transition between MIS 7 sub-stages. We maintain that these shifts reflect changes in the regional climate system. We thank the reviewer for raising this question and have added a more detailed explanation to the text.

- Figure 4. I would suggest adding to this ïňĄgure the duration of MIS7 substages (lines or shaded squares) to really see when they start and ïňĄnish, not only the "peak" indicated by the name in Fig. 4D.

Done

- Figure S3. I think these data correspond to two different laminae in every stalagmite. Please indicate it in the graph or caption.

We have replaced Figure S3 (see attached figures and response to first comment)

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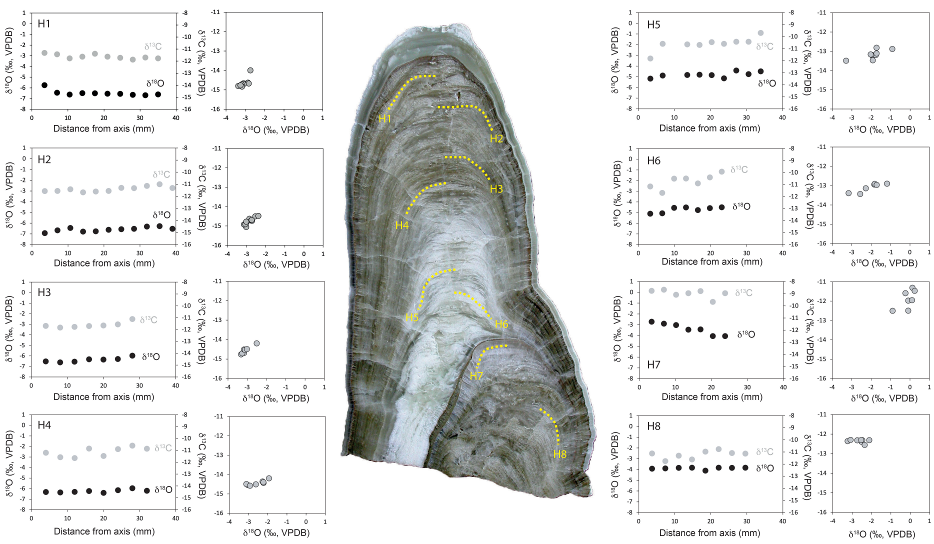

Fig. 1. New Supplementary Figure A (to replace supplementary figure 3)

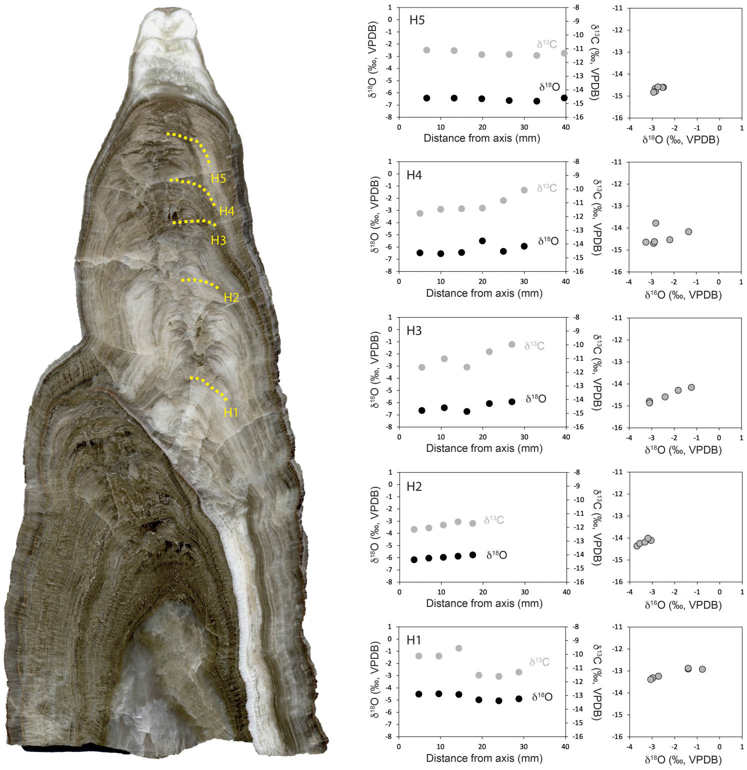

Fig. 2. New Supplementary Figure B (to replace supplementary figure 3)