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 1

R1 comment: Section 2.1 presenting the cave sites and speleothems could be shortened. Instead of a long and tedious text to read, it would be helpful to have an associated table in the main manuscript that summarizes at least some of the information provided in the text e.g. cave name, coordinates, elevation, air temperature and precipitation rate, associated sample acronyms, length of the samples...).

AC: this is a helpful suggestion, which we agree with and are prepared to revise the manuscript accordingly.

R1 comment: The discussion is also difficult to follow in Section 4.3, and the take-home messages hard to identify. The authors are investigating and discussing the roles of the different potential control factors on the calcite δ^{18} O records from the different caves. However, I feel that we are left without clear conclusions or discussion of the implications when no firm conclusion can be drawn. This section needs to be written in a more concise and structured way (the authors should consider breaking the text into sub-sections), with a better highlight of the take-home messages. When reorganising the discussion, the authors could have in mind the following key questions to structure the text: (1) what is investigated and on what scientific ground? (2) what is observed? Is it significant or not? (3) What are the implications and how to go further?

AC: indeed, it is clearly stated that "We appreciate that our investigation is only a first approximation, however, a more thorough investigation would require modelling which is beyond the scope of this study." Hence, firm conclusions are not drawn. This is the first time that we have a near complete view of the Northern Alps d18O calcite record, hence it is an opportunity to take a first look at the controlling factors. We agree this is long-winded, and will add a summary at the end of this section with the take-home message, which is that in the majority of cases, the d18O values are as we would expect – i.e. d18O becomes more depleted with distance from source (continental effect), and more depleted with elevation (altitude effect). We do, however, find that there are some anomalies to this, which seem to affect the very high altitude caves only – at times these are less depleted than would be expected.

R1 comment: I find the Section 4.1 on the coherence and updates to NALPS19 versus NALPS unsatisfying. I believe that more specific justifications for selecting one speleothem rather than another to build the new composite calcite δ 180 record are missing. For instance, it would be useful to provide a quantitative comparison (in a table?) for at least one or two periods (if not all) where there is overlap between "old" and "new speleothems" to better illustrate that the new ones are better dated and hence, more appropriate than the ones already published to constitute the new composite curve.

AC: for the most part, this is not a composite curve, e.g. the transition between Gl24.1 and GS24.1 includes GAS22, GAS29 and HUN14, whilst the transition from Gl21.1 to GS21.1 includes GAS12, GAS13 and SCH6 for the very reason that it is not possible to say that one speleothem chronology is better than another. The overlap between old and new speleothems is already provided as SI Fig 5. There it is possible to see the coherence between the new samples, and also to see that the precision of some dating is better than others (e.g. GAS 25 versus BA1 or BA7). The other information to draw on is that BA samples are slightly dirty, whereas GAS samples are not. We

mention that we have removed the 'dirty' samples where cleaner ones are available but are not explicit about which ones – we will change this accordingly.

R1 comment: My second general comment is that I find that many formulated statements, whether it is in the abstract or in the main manuscript, are too vague and/or miss some short background information. It renders the text sometimes hard to follow, especially for non-specialist readers. For instance, in multiple places, the authors state the good agreement of the different chronologies from the speleothem and ice core record within the dating uncertainties, without ever explicitly attached to their statement quantitative estimates of what those uncertainties are (pluri-decadal-scale? centennial-scale?).

AC: if the ages of specific events are the same within dating uncertainties, then to make statements about specific decadal, centennial timescales etc. would be to ignore those uncertainties. A better phrase maybe to say that 'events occur synchronously within dating uncertainties' rather than they are 'in good agreement within uncertainty'.

Another example is the lack of a short sentence providing basic information regarding the different ice core timescales discussed in the text. In the section 2 of my review, I point out specific places in the manuscript that require revisions. But the authors should go through the manuscript with this comment in mind and revise accordingly when appropriate. I detail below some specific comments and technical corrections that should be considered by the authors when preparing the revised version.

AC: this will be revised according to the suggestions later in the review.

R1 comment: Line 14: "...with highly similar shifts": this is vague, spell out clearly that you are referring to abrupt changes observed in the water isotopic profiles from Greenland ice core. I think also that one should be careful with the use of "highly similar", they are not the same proxy. If such comparison is kept, it should be specified in which sense they are highly similar.

AC: Agreed, this will be revised accordingly.

R1 comment: Line 18: It is necessary to specify in which term(s) the major transitional events between stadials and interstadials agree i.e. timing of the transitions and/or amplitude of the transitions? In the same sentence, it is necessary to provide also a quantitative average estimate of the uncertainties that are referred to here.

AC: Agreed, this will be revised accordingly.

R1 comment: Line 19: "...a good agreement between the NALPS19 speleothem δ 180 record, the GICC05modelextNGRIP ice-core δ 180 record and...." First, my comment is the same as previously, it is important to make it clear in which term the good agreement is.

AC: See previous comment.

Second, "GICC05modelext NGRIP ice core δ 18O record" should be reformulated. It needs to be clearer here that GICC05modelext refers to an ice core age model (it might not be necessarily obvious to all CP readers). It could be reformulated such as "the NGRIP ice core δ 18O record displayed on the GICC05modelext age scale".

AC: this seems very wordy but is clearer, it will be revised accordingly.

Line 21: "...too young" and "...a longer duration". By how much? Please be quantitative here and provide at least an order of magnitude.

AC: Agreed, this will be revised accordingly.

R1 comment: For clarity purposes, I think it is important that throughout the manuscript, the authors specify "calcite δ 18O" when mentioning the δ 18O records from the different speleothems and "ice δ 18O" and referring to the δ 18O from ice cores. They do it in places, but I think this should appear systematically to avoid any confusion.

AC: Agreed, this will be revised accordingly.

R1 comment: P2, line 40: While for further details, the reader can certainly be referred to the Erhardt et al. (2019), a few sentences need to be added to describe the added value of performing such analysis and the general principle and method used for the ramp-fitting of the transitions.

AC: Agreed, this will be revised accordingly.

R1 comment: SI Table1 could appear in the main manuscript and information could be removed from the section. AC: we consider such information to be 'extra' and not essential to understanding the manuscript; however, we can add more to the main text if desired. I found the information provided in the text very technical and from a non speleothem expert view, I feel that this should better be the supplementary material. AC: Agreed, this will be revised accordingly and produce a table. Instead the results section could be focused on the description of the different records and a detailed comparison of the timing inferred for the transitions in the paleoclimatic records using the statistical tool of Erhardt et al. (2019).

R1 comment: The authors discuss the relationship between calcite δ 18O and calcite δ 13C and perform Hendy test. Again, from a non-expert point of view, I would find it very useful to have a few of sentences explaining why they are performing such exercise, what they expect to be able to decipher from such investigation and finally what are the implications of the results of their test.

AC: Agreed, this will be revised accordingly.

R1 comment: P8, line 13: sentence starting with "Furthermore, despite...". Is there any explanation why the St Beatus records would record a signal that is different from the Gassel samples? It would be useful to provide more information on this.

AC: We do not know why some of the bigger-scale climate record appears to be missing from St Beatus, but we can add a sentence or two to explain this.

R1 comment: P9, line 5: The paragraph regarding the durations of GS-22 and the precursor event is difficult to follow. It would be very helpful if the authors could provide a table that summarises the different existing and new estimates of the durations of GS-22, GS21.2 and GI-21.2 in the discussed paleoclimatic records. Implications from their new NALPS composite curve should be expressed more explicitly.

AC: Agreed, this will be revised accordingly.

R1 comment: The numbering of the different sections needs to be revised. There should not be a subsection 1.1 if there is no Section 1.2 within the introduction section. I have a similar comment with the sub section 3.2.1, 3.3.1 and 3.3.4.

AC: This is not logical. The introduction didn't require a third independent section, hence there is no section 1.2. The results section is split accordingly: X Result. X.X Caves X.X.X. Samples. It would not make sense for specific samples to be a high level designation.

R1 comment: Figure 3.c. A sentence to explain the shift in calcite δ 180 values between the Asian monsoon composite records and the original data from which it was constructed need to be added.

AC: We consider this beyond the scope of this manuscript since this shift is a product of the work by the original authors who compiled the Asian monsoon composite. If the reader wishes to know further details, they should refer to the original work.

R1 comment: Figure 3. In the last sentence of the caption, "NGRIP nomenclature" should be replaced by "the latest INTIMATE event stratigraphy scheme".

AC: Agreed, this will be revised accordingly.

R1 comment: Figure 4. This figure needs to be reworked to improve its readability. A y axis scale is missing. Transitions should be numbered following the INTIMATE event stratigraphy scheme and it should probably also show the reference curves in the background the reference curves onto which they have performed the analysis. Also, it needs to be clarified what are the three panels in (c), which speleothem records have been used to perform the transition analyses. Again, this would be straightforward if the original curves were shown underneath or in parallel.

AC: Agreed, this will be revised accordingly.

R1 comment: Figure 6. This figure is hard to read. Efforts must be made to improve its clarity. For instance, a triangle symbol should not be used to represent different parameter se.g. in (a), the catchment elevation relative to longitude and in the other panels some stadial δ 180 values. For panels (e) and (g), "specific time periods" is vague, they should be specified. As far as I understand the caption for panel (f) is incorrect as only the mean δ 180 values for the speleothems covering some selected GI and GS are being shown relative to the catchment elevation and not all. Finally, the expression "Colours are the same as in (a)" doesn't need to appear after the description of every panel. The authors could simply write the colour code at the start of the caption stating that it is the same on all the panels of the figure.

AC: Agreed, this will be revised accordingly.

R1 comment: Figure 7. The authors should be explicit on which type of δ 180 values they are showing on the title of the axis e.g. ice δ 180 for (a), calcite δ 180 for (b) benthic δ 13C and planktic δ 180.

AC: Agreed, this will be revised accordingly.

R1 comment: FigureS7. More information must be given to understand clearly what is represented: Titles for the two y axes should be provided as well as a description in the caption of the different curves that are represented e.g. δ 18Odata,uncertainty ranges,probability density plots about the onset, mid-point and end of transition etc.

AC: Agreed, this will be revised accordingly.

R1 comment: P1, line 16: a space is missing between "using," and "eleven ".

AC: Agreed, this will be revised accordingly.

R1 comment: P1, line 21: Since it is not mentioned previously, it is important here to specify that AICC2012 refers to an ice core chronology i.e. "NGRIP ice δ 180 when displayed on the AICC2012 ice core chronology ", or alternatively, the acronym can be spelt out.

AC: Agreed, this will be revised accordingly.

R1 comment: P1, line 28: "precursor" instead of "pre-cursor".

AC: Agreed, this will be revised accordingly.

R1 comment: P1, line 29: to write "GS-24.2 COOLING event".

AC: Agreed, this will be revised accordingly.

R1 comment: P1, line 29: "...occurred shortly". Please be more specific so we have an idea from the abstract if you are talking about a few decades, or a few centuries, etc.

AC: Agreed, this will be revised accordingly.

R1 comment: P1, line 35: write "orbital-".

AC: Agreed, this will be revised accordingly.

P2, line 2: "...have been shown to be synchronous within dating uncertainties", please provide a reference to support this statement.

AC: The reference is already there, it is at the end of the sentence.

R1 comment: P2, line 7: There is no need for higher resolved ice δ 180 profile to identify the decadal and centennial-scale variability, it was already visible from the δ 180 profile published in NGRIP project members 2004. Only that no one had provided a specific description before the study by Capron et al. (2010). Hence, I think that the sentence should be rephrased.

AC: Agreed, this will be revised accordingly.

R1 comment: P2, line 9: write "centennial-".

AC: Agreed, this will be revised accordingly.

R1 comment: P2, line 14: "GICC05...." Add information regarding the time interval covered by each of the timescales.

AC: Agreed, this will be revised accordingly.

R1 comment: P2, line 32: the authors are correct about the age differences between the different chronologies and they should provide a quantitative estimate of them (at least an order of magnitude).

AC: Agreed, this will be revised accordingly.

R1 comment: P2, line 35: add a space between (ka) and (Boch et al. 2011).

AC: Agreed, this will be revised accordingly.

R1 comment: P2, line42: "a good agreement". Please be quantitative here regarding the agreement.

AC: This is difficult to comprehend. Since they are in agreement with respect to timing, how should one be quantitative unless the uncertainties are ignored? It would only be possible to be quantitative if they were out of agreement or the uncertainties are not regarded.

R1 comment: P3, line 3: why 1.1 Regional climate while there is no 1.2 and it follows the long introduction that doesn't have a sub-section heading.

AC: There is no 1.2 because the next topic is methods and therefore requires the beginning of a new chapter. We consider Regional Climate to be Introductory Material, but could also consider it placing it as its own section 2. Regional Climate

R1 comment: P3, lines 17, 20 and 21: Northern Alps and Southern Alps.

AC: Agreed, this will be revised accordingly.

R1 comment: P3, line 23: The formulation is awkward and should be rephrased with a more direct style.

AC: Agreed, this will be revised accordingly.

R1 comment: P3, line 32: space is missing between (2015) and (though.

AC: Agreed, this will be revised accordingly.

R1 comment: P5, line 26: for clarity purposes, please write instead "samples from Baschg Cave" and similarly in the titles of sub-sections 3.2, 3.3, 3.4 and 3.5.

AC: Agreed, this will be revised accordingly.

P8, line 29: here and throughout the manuscript: Erhardt et al. 2019 (not 2018).

AC: Agreed, this will be revised accordingly.

R1 comment: P9, line 2: In the paper by Columbu et al. (2017), a well-dated Sardinian speleothem covering GI-25b and GI-25a is presented. The timing of the abrupt transitions is also discussed and compared relative to the timing of the same events when displayed on the different Greenland ice core timescales. This study also provides evidences that there is a good agreement between the transition timing in the speleothem record and when considering GICC05modelext timescale, but that when considering the AICC2012 chronology, ages are younger by several millennia. The authors should mention this study in their manuscript.

AC: Agreed, this will be revised accordingly.

R1 comment: P9, line 3: The sentence should be completed: "...too young by about XX yrs".

AC: Agreed, this will be revised accordingly.

R1 comment: P9, line 7: The formulation of the sentence starting by "This demonstrated...." is awkward. It needs to be reformulated.

AC: Agreed, this will be revised accordingly.

R1 comment: P9, line 13: I don't find the information in brackets necessary, it can probably be removed.

AC: We disagree, it is important to be explicit about what the datum is, otherwise these ages spread inaccurately throughout the literature.

R1 comment: P9, line 22: I find the title of the section 4.3 quite vague and not really appropriate. The authors should try and be more specific.

AC: Agreed, this will be revised accordingly.

R1 comment: P12, line 11: centennialP12, line 14: space between (Fig. 7) and (Capron...).

AC: Agreed, this will be revised accordingly.

R1 comment: P12, lines 13 and 27 and P13, lines 17, 18, 20 and 22: The use of the word "termination" should be avoided in this context and replaced by e.g stadial-interstadial transition. Indeed, as the authors know the word "termination" is classically used in paleoclimatology to refer to glacial-interglacial transitions and I think for clarity purposes, it is preferable to avoid introducing this term in a different context and to refer to a different climatic event.

AC: Agreed, this will be revised accordingly.

R1 comment: P12, line 19: "Changes IN Ca2+" rather than "Changes TO Ca2+". Also, I don't find the reference to Rasmussen et al. (2014) appropriate in this context. Instead I would suggest referring to the studies by Ruth et al. (2007). U. Ruth et al., Geophys. Res. Lett. 34, L03706, 10.1029/2006GL027876 (2007).

AC: Agreed, this will be revised accordingly.

R1 comment: P12, line 25: "the NGRIP nomenclature" should be replaced by "the INTIMATE event stratigraphy scheme".

AC: Agreed, this will be revised accordingly.

R1 comment: P13, line 13: space between (Wang et al. 2004) and (Fig. 7).

AC: Agreed, this will be revised accordingly.

R1 comment: References

AC: Agreed, this will be revised accordingly.