Dear Dr Reyes,

We are grateful for the constructive comments and helpful suggestions by the reviewers. Below is a point-by-point description of made changes to the manuscript as a response to the major comments and questions raised by each reviewer.

Comments by reviewer #1

The authors describe how CCMs are a paleo-permafrost proxy and their importance to mid- and lower-latitude sites. What do the presence of CCMs in this northern-most location tell us about permafrost in this high-latitude site? It's clearly interesting that these CCMs appear to have formed during a short-term extreme event on the ice sheet in 1889. A little more context of why this is an important finding in the Discussion and Conclusion sections would be helpful for the broad audience of this journal.

We have changed the phrasing in the introduction to make it clearer that CCC_{fine} cannot be used as palaeo-permafrost proxy (LINE 44).

We have added more context to the Discussion and Conclusion sections in LINES 370-374 and LINES 393-396, describing how the CCMs can be used to reconstruct the spatial extent of melting conditions in an area outside of the ice sheet and how linking their formation to the summer melt episode of 1889 CE provides hints about the rate of formation.

The closest ice core record would be from Flade Isblink, and the authors report that this record does not suggest excess melting in 1889, but a recent publication shows that there was a high concentration of black carbon in 1889 at Flade Isblink (Eckhardt et al., 2023). Understandably, the perfect ice core record does not exist to prove the theory that these CCMs were formed due to excess meltwater from the 1889 widespread melting event that occurred at higher elevations on the Greenland Ice Sheet. With the increased concentrations of black carbon at the Flade Isblink site so close to Cove Cave, it does appear that the melting event could have happed in this region too. I suggest including the Flade Isblink black carbon record to bolster this hypothesis.

We have included the mentioned record/publication in the manuscript (LINES 360-361).

Specific comments

We have changed the manuscript according to all of the reviewer's suggestions in this section.

Figure 1: are the blue lines indicating ice margins referring to present-day ice margins, or ice margins from the former presence of additional ice caps that are mentioned in the last sentence of the figure caption?

We have changed the figure caption and added "(light blue polygon)" and "(blue lines)" to the respective sentences.

Comments by reviewer #2 – Connor Turvey

37 – It would be good to explicitly state the criteria for differentiating CCC_{fine} from CCC_{coarse}, presumably a grainsize limit.

We have added a statement on differentiating criteria to the introduction (LINES 36-39).

70 – It would be better to report an approximate distance from Cove Cave to the weather stations rather than just saying 'closest'.

The approximate distances are now included in the manuscript (LINES 74-75).

83 – A quick definition for what 'inactive' means in this context might be helpful, presumably it is common in speleothem geology but I am unfamiliar with it.

Done (LINE 88).

91 – Should probably change "rather low" to something less casual.

Done (LINE 97).

105 – Were there any obvious visual differences (color, texture etc) between the samples during collection?

There were not. We have added a sentence to the text (LINE 111).

110 – Clarity could be improved here, are you taking sample KC19CCC-4, splitting it into different mineral fractions and then mixing the relative amounts? Or are you mixing KC19CCC-4 with another phase?

We have changed the phrasing to improve clarity, stating that the sample was split into different mineral fractions and the relative amounts were mixed (LINE 116).

116 – More analytical details for the mineralogy and crystal morphology analysis would be good. For example, with the XRD what was your scan range and analysis time?

We have added more detail (LINE 121).

166 – Why could you not ID the very fine brownish crystals? Even if it was too fine to manually separate under a microscope for analysis you had XRD data and could identify the other crystals in the sample so I would have thought it should be possible by process of elimination.

We have added the most likely composition of the very fine brownish crystals based on the XRD results (LINES 172-173).

171 – An XRD figure either here or in the appendices showing the results from the 4 samples would be very useful as it would allow for easy comparison between the mineralogy of the four samples, rather than just having it written out.

We have added X-ray diffractograms to the appendix.

249 – SEM may provide useful insights here, were any textures observed that could only be explained by synchronous formation (crystals intergrown etc)

We have added a statement that the examination of SEM images yielded inconclusive results (LINES 263-265).

250 – Any idea where does the quartz, dolomite and potassium feldspar in KC19CCC-1 come from? Country rock?

We have added the most likely sources to the manuscript (LINES 259-261).

280 – No theory as to why your difference between δ18O values of your CCCfine vs. common speleothems is different to that seen in other studies?

We have added our hypothesis to the text (LINES 294-297), saying that the isotopic composition of the source water differed.

314 – Would be good to have a reference supporting your claim that there are not CCMs overserved in other caves in the area.

To the best of our knowledge, there are no other references to support this. We have added to the text that the statement is based on the findings of two expeditions that were part of this project (LINE 331).

Comments by reviewer #3

I am particularly intrigued by the interpretation of "a few days," specifically at LINES 23-24: "We relate the CCM formation to a combination of black carbon deposition and anomalously high temperatures, which occurred over a few days, in the summer of 1889 CE." The time constraint of "days" is an extraordinarily statement – the fact that a few days of extremely high temperatures caused widespread melting over northeast Greenland is an important finding, if it's true. However, I find the author's reasoning for relating CCM growth to this extreme climate event (a few days of warming) insufficient. There is not a thorough explanation for why authors jump to "days"? In the paper, the only citation is Neff et al. (2014). The authors need to add more explanation to this interpretation.

We have rephrased LINES 351-357 to make it clearer that the time constraint of "a few days" was not deduced by our samples but is based on a study by Neff et al. (2014). The summer melt episode of 1889 CE itself is recognised in several publications.

Abstract: I am not sure why authors include the information about CCCfine δ18O values in the abstract? It is my understanding that they do not use this data to make any interpretations?

We have removed the stable isotope values from the abstract.

Line 39: Though the authors link CCC formation as a "useful proxy for paleo-permafrost," they do not state clearly whether the formation of CCC=permafrost is present? It may be worth stating this explicitly for readers who are unfamiliar with CCC.

We have added a clear statement regarding this (LINES 41-42).

Line 40: Please state the size difference between CCCcoarse and CCCfine. Are CCC samples separated into "coarse" and "fine" categories by eye? By measurement?

We have added a statement on the differentiating criteria (LINES 36-39).

Line 45: Is there a reason the authors report the CCM subtypes as CCC_{coarse} and CCC_{fine} versus CCM_{coarse} and CCM_{fine}? Lines 37-45 explain the difference between CCC and CCM, but then authors refer their CCM samples as CCC? Please clarify, because right now it seems these two are equivalent.

We have dropped the term CCC_{fine} when referring to the carbonate fraction of our samples throughout the manuscript.

Line 48: "recently called into question." How? Please briefly state this. Perhaps move line 50 up to follow this sentence, since I believe it's because of detrital thorium contamination?

We have included a statement to better explain this (LINES 50-52).

Figure 4: It is difficult to discern the difference between the light vs. darker gray shading colors. A suggestion to make one of the categories black?

We have changed the colours in Figure 4.

Line 125: Please specify where common speleothems were collected. Was it the same cave? Right now it is just reported as "in the study area," which is not enough information. This could help shed light on the δ18O difference between common speleothem and CCCs?

We have specified where the samples were collected and have added the spatial extend of the study area (LINES 131-132).

Section 5.2: Are authors interpreting the low δ18O values as reflecting contribution of precipitation from the Arctic air mass? Doesn't this location primarily receive precipitation from the Arctic air mass? Why is this significant? Also, the Greenland common speleothems have a higher δ18O value than CCM δ18O, but they were collected from the same cave? If they are from the same "northeast Greenland" cave, then they should receive precipitation from the same source, and therefore should have the same δ18O? I see at Lines 278-281 the authors address this difference, but do not provide a reason why? Please explain? Even if the authors are not sure why this is, that should be stated. As of now, it is unclear what the assumption of this is, and I find the discussion of the stable isotope data not sufficient.

We have changed the whole paragraph to focus on the latitudinal shift towards lower $\delta^{18}O$ values that can be observed in cryogenic cave minerals as well as common speleothems (LINES 286-288).

We have also added a hypothesis that the isotopic composition of the source water differed between CCMs and common speleothems from Cove Cave (294-297).

Section 5.2 (continued): What is significant about the Greenland CCMs δ18O overlap with mid-latitude caves? This is not discussed, and I'm a bit confused why this is significant.

We have added a statement in LINES 289-291 to explain the significance of this finding.