Dear Dr Pain and co-authors,

Thank you for your response to reviews. I must apologise for the delay in responding to your comments. I have reviewed the responses and would now like to invite you to proceed with the upload of your revised manuscript.

Please consider the reviewers' comments carefully. In particular, Reviewer 2 expresses some concerns about the validity of your assumptions when interpreting the data. I, and the two reviewers, believe that you have an excellent and hard-won dataset, but both reviewers express some concerns in the interpretation. Please consider their advice carefully before resubmission. When you address the comments from the reviewers, to which you have detailed your responses, I also request the following amendments to the manuscript:

> Thank you very much for your evaluation and helpful suggestions. We likewise apologize for the delay in uploading our revised manuscript. The revision included the inclusion of new hydrologic data that had to undergo quality control prior to inclusion in the manuscript, which extended the time needed for the revision.
>
> We have taken many of the reviewer suggestions into consideration and believe our revised manuscript is significantly improved in the clarity in the presentation results and reduction of assumptions. The major changes to the manuscript include:
>
> 1) As suggested, we have renamed our "Isunnguata" site as "sub-Isunnguata" to reflect that this site is not the main drainage channel of the Isunnguata. The modification to the text can be found in lines 86-99.
>
> 2) Our previous version used Watson River average daily discharge to assess the relationships between discharge and greenhouse gas dynamics, however Reviewer 2 raised questions about the use of Watson River discharge data, which drains a large watershed area (up to 12,600 km^2; Lindbäck and others, 2015), compared to the individual drainage areas of the sub-Isunnguata (watershed area ~40 km^2; Rennermalm and others, 2013) and Russell Glacier (watershed area <900 km^2; (Hawkings et al., 2016). This new revision therefore uses discharge data from a segment of proglacial river downstream of the sub-Isunnguata sampling site (site AK4; Fig. 2b). Discharge records from this site have been used to evaluate the glacial hydrology of the sub-Isunnguata watershed in other studies (e.g. Rennermalm and others, 2013).
>
>   We also use AK4 discharge data to assess concentration-discharge relationships from the Russell Glacier. Although this site is upstream of the Russell Glacier, it is much closer to the Russell Glacier than the downstream Watson River PROMICE gauging station (van As et al., 2018) that receives meltwater contributions the Akuliarusiarsuup Kuua (draining the sub-Isunnguata, Russell, and Leverett catchments) as well as the much larger Qinnguata Kuussua. We therefore believe that Watson River discharge records are likely to be less representative of the temporal changes in the magnitude and variability of discharge from the much smaller Russell

glacier catchment. Since our evaluations are not intended to be quantitative, we believe using AK4 discharge records to evaluate Russell discharge-concentration relationships can still provide valuable information regarding the hydrologic controls of CO_2 and CH_4 dynamics in this region. This addition of sub-Isunnguata discharge data and the resulting interpretations represent significant improvements to our ability to assess hydrologic controls of greenhouse gas dynamics under the Greenland Ice Sheet, therefore we have made Asa Rennermalm a co-author on this manuscript.

3) We have presented the data from multiple years (2017 and 2018) as individual data series by removing lines between data points in plots that show chemistry versus day of year (e.g. Figs 3, 4, 6, 7). This change more clearly presents data as being collected over multiple years and addresses comments from Reviewers 1 and 2.

4) We have removed the results of a CO_2 isotopic mixing model (previously Fig. 9) because of the number of assumptions embedded in this analysis. The newly included discharge data for the sub-Isunnguata indicated greater variability in the relationship between discharge and concentrations of putative CO_2 sources, therefore we deemed this analysis too speculative to include in the revised version.

5) We have added a new figure to present discharge versus CO_2 concentration and isotopic compositions (Fig. 8). Concentration-discharge analyses for this dataset are now much more robust due to the new discharge information for the sub-Isunnguata watershed.

As well as considering the place name nomenclature suggested by Dr Graly and the nominated reviewers, please consider whether you can replace the 'Watson River' with the Greenlandic name, Qinnguata Kuussua or Akuliarusiarsuup Kuua, as appropriate. Also note that in Figure R5 in your reponses, you label Isunnguata Sermia Glacier: this is nonsensical (Sermia broadly translates as glacier), so please remove the extra 'Glacer'. I strongly support Reviewer 2's request to amend the naming of the 'Isunnguata Sermia', since your data do not represent the wider Isunnguata Sermia catchment. Perhaps you could consider subIsunnguata, Isunnguata-Russell or lateral-Isunnguata, or some other better version that does make it clear that this is a sub-catchment, not the main trunk which drains into Isortoq. The map in R5 is very useful for context, and perhaps an expanded version also showing the main trunk of Isunnguata Sermia to the north could be added to the map figure.

We thank you and the reviewers very much for indicating these important place name clarifications. We have modified the map figure (Fig. 2) to indicate the positions of the Isortoq, Qinnguata Kuussua and Akuliarusiarsuup Kuua, as suggested, and have preferentially used these names (rather than Watson River) throughout the text.

We have additionally renamed our Isunnguata sampling location as the sub-Isunnguata location. The site descriptions also now provide more detail about local hydrology (lines 86-105).

The markers on the map (Figure 2) are very large, meaning it is quite hard to see exactly where the samples were collected. Please could you reduce the size? I also find Figure R1 quite garish: the markers again overwhelm the map. The boundary could be more subtly delineated without detriment; although I do wonder at the utility of this map – I do not think the geological boundary exerts much influence over your sampling sites, since they both lie to the north.

> We have redrawn the map figure to address this issue (Fig. 2)

I agree with Reviewer 1 on the presentation of the NH4 data: it doesn't add much to the story, so wonder if it really needs to be in the manuscript. I appreciate your justification in the response, but I am unconvinced that the data really help in the exploration of the carbonate processes – it seems a rather weak association with the organic matter remineralisation hypothesis.

> We have taken this suggestion and removed the NH_4 data from the manuscript.

Does the Pitcher et al. 2020 paper not show that there is only winter flow in the main Isortoq outlet? From my understanding of your sample sites, and the clarifications in your responses, your samples were not collected from Isortoq, but from Akuliarusiarsuup, which experienced no winter flow. Please consider this in your revised description of the flow regimes (as requested by Reviewer 1).

> We have revised our description of the flow regimes in the region (lines 86-105) as well as the presentation of locations in the map figure (Fig. 2)

In your response to Reviewer 2, you include some site photos. These are very useful and I hope these will be included in the Supplementary info, or incorporated into the manuscript somehow. Please could you indicate the direction you are facing when the photo is taken? The Isunnguata one is hard to orient. One note: a 'boil' is not a common term in glacier hydrochemistry. Could this be a small subglacial upwelling (eg. Wadham et al. 1998; Irvine-Fynn and Hodson, 2010)? I also agree with Reviewer 2 in the assessment of the slow flowing section of the terminus of Kiatuut Sermia as a 'lake' rather than a slow flowing section of river (I have in fact kayaked and depth sounded this lake, see Beaton et al. 2017 and Bagshaw et al. 2014). It is hard to see from Figure 2 exactly where your sampling site was, but if it was downstream of this feature, it will impact the residence and transit time of water from the subglacial environment to the sampling site. The presence of this lake should be acknowledged in your revised manuscript.

> We include site photos in supplementary information, along with an indication of the direction the photo was taken. We also rename the boil as a subglacial upwelling, and revise our description of the lake at the Kiattut Sermiat site (lines 127-131) and in the supplementary information.

Your defence of the manuscript in the final paragraph of your response to Reviewer 2 is commendable. I wonder if some of this material could be used in your concluding statement in the main text? The current conclusions are very focussed on weathering implications, and do not really demonstrate the utility of this study to an audience beyond the glacier weathering

community, whereas your defence articulates it very well! Thank you for your patience with the review process; I look forward to reading the next version of the manuscript.

> Thank you very much for this suggestion. We have revised the conclusions to be more inclusive of the broader implications of this work beyond the mineral weathering community (lines 514-536). We very much appreciate your helpful feedback throughout the review process and believe the revised manuscript is a strong improvement from the previous submission.

Dr Liz Bagshaw Editor