Response to Referee #2

We appreciate the supportive tone and considerate comments that Referee #2 provided on our manuscript. The Referee's opinion that the manuscript is "*well written and nicely presented […], which has the potential of becoming a welcome addition to the body of literature*" is encouraging and the list of specific comments will be very helpful in improving the overall presentation and interpretation of our data.

The Referee's overarching general comment is that our sampling strategy relying on a small number of grab samples may not adequately capture the isotopic and chemical variability in the seasonal snowpack, as has been well established by previous field studies. We appreciate that the Referee acknowledges the reality of the inherent challenges in collecting large numbers of snow samples in a mountainous field area, and we certainly wish we could have collected more and from earlier in the season. However, such an expanded sampling campaign was simply not possible. Thus, we are left with the samples we have and need to rely upon them, with their imperfections, as the sole source of information about the composition of the snow contributing meltwater to this system in 2021. In our revisions we will endeavor to more explicitly address this as an understandable but unavoidable limitation of our study, and to explore ways in which this limitation might carry over into our interpretations. The references suggested by the Referee will be very helpful in expanding this part of our paper. Ultimately, we are confident that our general conclusions are robust and are not substantially undermined by the uncertainty driven by the small number of snow samples. But we agree that we should do more to explicitly explore this for our readers.

The Referee also notes that our calculations comparing the subsidence volume on RG-2 with the estimated spring discharge seems like a "last minute" addition to the paper. However, we intentionally bring this in at the end of the discussion because our numbers are inherently imprecise (both the timing of when the observed depression formed and the true rate of spring discharge cannot be known). Thus, we are merely endeavoring to note that there is evidence of subsidence and that the magnitude of that subsidence is compatible with relatively recent change in the mass balance of ice in this rock glacier system. If we had more robust measurements, we could make this a more central part of the discussion. But given the uncertainties, it seems prudent to include this as more of a supporting note, rather than a main argument. Nonetheless, in our revisions, we will explore how to make the transition to this section smoother so that it doesn't seem like an afterthought.

Specific Comments (*with our response in italics*)

L77. Probably you mean that no *clean glaciers*, remain in the Uintas.

-The best way to distinguish "ice glaciers" from "rock glaciers" with minimal wordiness is elusive. Here we meant "ice glaciers"; perhaps "clean glaciers" is a better way to phrase that.

Fig1. This figure could be complemented with a layer showing the delineation of known rock glaciers in the basin. Is the Spring sampler upstream of the Stream sampler? it is not clear from the figure.

-We can easily add the mapped rock glacier outlines to the figure, and will clarify the relationship between the different samplers. Thank you for the suggestions.

L90. Replace "samples" with "samplers".

-We will make this change.

L107-109. Were these data loggers active for this research? if so, their location should be shown in Figure 1.

-The data from the loggers were presented in the referenced paper (Munroe, 2018). They were located at the same positions at the water samplers in this study.

L115. This range of flow is 1 to 2 orders of magnitude larger than the discharge from RG-1. Why might this be? Before, you say that both glaciers are "600 m long and 100 m wide". Can you be more specific and provide surface area estimates for each rock glacier?

-Flow estimates from rock glaciers are notoriously difficult because so much of the water can drain below ground, flowing through the rocks. We suspect that is the explanation for the difference between the estimates for these two springs. The rock glaciers are about the same size, but we can certainly add more specific dimensions including areas.

Methods section. Please provide accuracy estimates for isotopic signatures based on the analytical procedures and instruments employed.

-We will add these estimates in our revisions.

L151. Replace "was" with "were".

-We will make this change.

Figure 3. Why are samples from RG1 not shown in this figure? I can't see a mention to this in the text.

-It was not possible to return to the more distant RG-1 sampler early in the season to collect a subsample as we done with the other more accessible samplers. A note explaining this will be added to the text.

Table 2. RG1 samples seem to be less depleted than those from RG2. Is this difference significant?

-The difference is statistically significant, we will note this in our revisions.

Figure 4. Why are snow, rain and melt samples not plotted in this graph? the number of samples in these cases is very low, but nonetheless it would be interesting to see where they fall in the graph.

-We omitted snow, rain and melt samples in Figure 4 for clarity, but we presented their ranges in Figure 6. We will explore whether it is possible to present them in both places, but want to avoid compromising clarity of the figure.

Figure 5. Why are symbols for RG2 in July different?

-As noted in the figure caption, the small green diamonds present reconnaissance data collected for RG-2 in the fall of 2020 during a preliminary phase of this project.

Figure 6. It makes little sense to plot snow values as an average, with so few samples. Better just plot the individual samples in the graph. Same with snowmelt.

-Our logic in presenting the range was to acknowledge that our understanding of the exact snowmelt values is imperfect; presenting the range was a visual way to highlight this uncertainty. We can explore whether presenting the individual values provides the same effect.

L250. The technique is called "principal" component analysis. Please review and correct throughout the text.

-Our mistake, we will make this change throughout the text.

Figure 9. It would be nice to try and discriminate the water samples among stream, spring and rock glaciers. Maybe you could select major ions and plot in this graph as well.

-Good suggestion, we will explore ways to discriminate between the water samples with color and/or symbols.

L311. This inference might be correct, but I think that it is unsupported by the available data, which is very scarce in terms of snow and snowmelt isotopic composition.

-True, our number of snow samples is small. But here we are noting the correspondence between the similarly depleted isotope values for both snow and groundwater, and emphasizing that groundwater values are most depleted. The most logical explanation for that observation is that groundwater is primarily derived from snowmelt.

Snow at different altitudes can have a large spread in the isotopic signal, and melt can favor preferential elution, which muddles the picture when trying to link stream and snow samples.

-True, we will be sure to include mention of this in the revisions we make.

L318 and elsewhere: please use a more direct time referencing to help the reader follow your analysis. Talk in terms of specific months, at the very least.

-Thank you for the suggestion, we will endeavor to do so in our revisions.

L318. low values of what?

-As we are referring to the GMWL here, we thought it would be clear that we are talking about low value of deuterium and $\delta^{18}O$. We will make this clearer in our revision.

L333. these large reservoirs have not been described previously in the text (except for one lake). They should be mentioned in the study area description and their storage volume at least approximately quantified.

-We apologize if that was unclear; we are not referring to artificial water reservoirs,

rather we are noting that the spring and the stream systems are larger and more voluminous than the two rock glaciers, thus they would be more likely to exhibit stable values during the melt season.

Figure 10. In this end-member mixing analysis, error bars should be provided, moreover considering the very low number of snow samples.

-We will explore how to include this information in our revision.

L384. "Thus these samples…" Yes, but may not necessarily be a valid representation of snow MELT at this time, or of basin-wide snow composition, because of preferential elution and spatial (elevation-dependent) isotopic signatures of accumulated snow. The authors must discuss this source of uncertainty and incorporate somehow in their estimates.

-We will include a more robust exploration of this uncertainty in our revision. Nonetheless, the fact that our small number of samples yields isotope values similar to other collections from the region and to values predicted by the OIPC supports the assessment that our samples are not terribly influenced by post-depositional effects.

L389-395. the fact that this potential bias in the data (originated by the road) is brought up this late in the paper seems problematic to me. Are these data included in all the previous analysis? Why? should this data be discarded altogether?

-We agree that the possibility that road dust influenced the precipitation samples collected at the spring site is concerning. This is why we relied on the precipitation collected at RG-2 (far from any road) to constrain precipitation chemistry (Lines 394-395).

L403. The authors should discuss why this significant estimated contribution from RG is not reflected in the stream isotopic composition time series, which remains stable although there's a strong trend in the RG series (figure 6).

-In reality, only the spring (groundwater) time series is stable (Figure 6); the streamwater does exhibit rising isotope values late in the season that are consistent with an increased rock glacier component.

L413. but you also estimated 15 l/min for one of the glaciers. So, the rate of ice melt is hugely uncertain! Although this surface depression analysis is interesting, the way it is presented here feels rushed and somewhat contrived. The authors should expand: what is the total area of RG mapped in this basin? what is the range of glacier ice available? etc.

-We previously discussed our logic in presenting the implications of this surface depression so late in the discussion. We will work to make sure this doesn't seem like an afterthought, while simultaneously balancing the reality that are calculations are imprecise. We could certainly add mention of the total area of rock glaciers mapped in the basin, and we previously mention that glaciers are absent in this region.

Figure 12. I'm afraid that I can't see the depression the authors refer to. This data should be presented much earlier, in the data section, and not in the discussion section.

-We agree that the depression is difficult for some to see given the direction of the apparent illumination in the surface model underlying the photo mosaic. We can adjust this in our revisions. As we have discussed already, given the uncertainties we feel it is prudent and appropriate to include description of this depression and its possible significance late in the discussion section. We will adjust the presentation though to make this transition smoother.

L428. Based on only one sample of snowmelt water, it is tenuous to make strong statements about snowmelt similarity or influence on streamflow throughout the season. This is a major problem of the material presented here, and should be discussed by the authors.

-As noted above, we will be certain to include a more explicit consideration of the limitations imposed by the small number of snow samples. At the same point, we obviously cannot go back in time to collect more snow and the Referee acknowledges the inherent difficult in making large-scale snow collections in such terrain. We are encouraged that the values for the samples we do have match so well with other reported isotopic values in snow from these mountains, and with the values predicted by the OIPC algorithm. We consider both of these as solid lines of support for the snow values we were able to directly measure.