Response to Reviewer 1

Thank you very much for taking the time to review our paper. Please find below our responses to your comments. *Reviewer statements are in italics.*

"This appears to be a poorly conceived study or, at least, a poorly conceived description of the study. It reproduces a key inference from a paper published six years ago and presents it as a new result or inference."

This study is the first demonstration of how the opening of a long valley in the bedrock can impact the subglacial hydrology and ice sheet sliding in northern Greenland. The results show that even small adjustments in the bed topography to include probable features can have consequences that could affect future simulations of the ice sheet. Bamber et al. 2013 (B2013) did not demonstrate that an uninterrupted water pathway was possible from Interior to Petermann. Their figures show water pathways along numerous independent sections of the valley. They infer that the valley is probably continuous but do not present scientific evidence of the potential effects the continuity of the feature could have on the basal hydrology or ice sheet sliding. Our results are new and we hope will be useful for progressing forward in our understand of subglacial valley features. Areas of the introduction and discussion can be reworded to reference the inferences made in B2013 which we hope will address this concern.

"As mentioned in the already posted comment, this study is actually about the influence of a continuous subglacial canyon on water flow and ice dynamics. While that is a topic that could be interest, almost all of the discussion presents flawed, hand-waving supposition that has little evidential basis and has little, if anything, to do with the model experiments."

The discussion outlines the potential significance of the valley based on the model results and current form of the ice sheet and known bed topography. We are combining the techniques of model analysis with observational data and discuss the implications in the context of past research on subglacial hydrology. Responses to specific comments raised concerning the discussion are below.

"The paper would benefit from a substantial rewrite and refocusing on the actual topic of the experiments conducted: what is the impact of a continuous canyon on the subglacial hydrology beneath the Greenland ice sheet? However, as the hydrology model used assumes thin film flow and no sources from surface melting are included, it is debatable to what extent the experiments can address this question with adequate confidence."

We are making changes to the manuscript to firm up our investigation, including making discharge estimates. The thin-film model is used as a guide for where subglacial water is moving and collecting under the ice sheet.

Contributions from surface melting to basal water are currently impossible to accurately assess but would only serve to enhance the probability of a subglacial river being present within the valley. Given the path of the valley mostly within the ice sheet interior, it may be difficult for surface melt water to reach the base, at least under present conditions. It's an interesting and important issue and one that can be mentioned in the discussion.

Specific Comments
1) As already mentioned in the posted comment, the title is not only extremely misleading it addresses a question that was tackled previously and this study provides no new evidence to answer it. The entire abstract needs to be rewritten focusing on the results of the model

experiments and nothing else.

The finding of an uninterrupted water pathway along the valley from Interior to Petermann was not demonstrated in previous work. B2013 Figure 3 demonstrates the effects that errors in bedrock data have on water pathways that consequently fail to follow the valley route. We demonstrate for the first time the potential consequences of accounting for these errors by opening one single valley. We think it is better to use model results in conjunction with observations for this type of study rather than solely focus on the model results.

2) It is unclear to me why the authors have to introduce or replace existing terminology. They need to remove the word "river" throughout and replace with either conduit, R channel, or thin film as appropriate. In addition, why do they rename the canyon, "valley". Their explanation (p1, l23) is nonsensical.

The term "subglacial river" is used here to cover a variety of possible subglacial river forms such as within R-channels, canals, Nye channels, or braided rivers. We will add our definition of this to the introduction.

We use the term "valley" because in areas of the interior the feature does not appear to take the form of a canyon as for example defined as "a deep valley with steep sides". In regions the valley does not have steep sides, so we think the broader term "valley" is more appropriate as it better accounts for a wider range of forms. In work prior to B2013 the feature was referred to a "bedrock trough" or "trench" by Ekholm et al. (1998) , and a "channel" or "subglacial valley" by van der Veen et al. (2007). In addition, the term "tunnel valley" has been widely used for subglacial water incised channels. The terminology can be changed if the editors, reviewers and co-authors think that "canyon" is a more appropriate term to use for the feature as a whole.

3) The introduction is misleading and needs to be rewritten. Quoting directly from Bamber et al 2013 (B2013), they state "we present evidence from ice-penetrating radar data for a 750-km-long subglacial canyon in northern Greenland that is likely to have influenced basal water flow from the ice sheet interior to the margin"; "In all cases, above ~76° N and within the entire length of the Petermann catchment, the canyon exerts a control on basal water flow. For ~200 km, it provides an uninterrupted hydraulic pathway (Fig. 3 and fig. S3A) that ends at the terminus of Petermann Gletscher" and so on. I do not understand why the authors are proposing this as something entirely new.

These are not the same as the results are presented in our paper. B2013 present evidence in their Figure 3 of water flow along some sections of the valley but not along the whole length in any of the scenarios. With present day ice sheet cover they find an uninterrupted water pathway for only the northernmost section ~200 km in Petermann catchment as stated. This demonstrates the strong forcing for water flow along this section when ice is present because this occurs even in these cases that contain large and unrealistic artificial blocks in the valley. Nonetheless even in these cases, it is worth noting that water is diverted away from the valley just prior to entering the Petermann Glacier basin due to a large artificial block in the bed topography there. This error also occurs in the results of Chu (2017) Figure 4.6c. Further inland the situation is more serious with water flowing in and out of the valley in numerous locations in all of the cases presented in B2013. The only result in our paper that is similar to the distribution in B2013 Figure 3c is our Figure 4a which presents our control case. This is because it also contains these unrealistic blocks in the valley.

4) P2 l1. The authors appear to be unaware that the bed topo in BedMachine v3 and that which was used in B2013 are essentially the same. The only difference is in the use of mass continuity near the margins where IPR coverage is poor. Any conclusions drawn in B2013 will be identical

for BedMachine.

Our tests are focused on the effects of the removal of blocks in the valley in BedMachine v3. We are not presenting any results or discussion concerning differences between BedMachine v3 and the data used in B2013.

5) P4, l35. Fig 5 does not show slope, it shows surface elevation. The slope in the interior of ice sheets is small everywhere. This is not the same as "near flat" which is meaningless. Eyeballing the Fig it looks like the canyon follows the surface slope quite closely in the interior. This sentence is a good example of the hand-waving vagueness that pervades other parts of the paper.

We can change the terminology from "near flat" to a more appropriate term. The valley progresses down under a very gentle ice surface slope that would not oppose subglacial water flow in its base.

6) P5, l5-6. I don't understand the logic of this statement. The canyon is not linear and doesn't follow the streamlines when it is not present (Fig 4a). This is nonsensical

In this section we are trying to establish whether the current form and path of the valley is consistent with what could be expected for a subglacial river under the current ice sheet configuration. While the valley appears to intersect the east and west hydrological basins in the interior it does not follow the streamlines, particularly as it crosses NEEM zone. A perfectly aligned valley with present day streamlines is probably not to be expected given the different extents of the ice sheet in the past. B2013 Figure 3b is a good indicator of this as the basal hydrological divide is shifted to the west under LGM conditions and the valley still follows a path not far off the basal hydrological divide. We can reword and add some sentences discussing this issue and reference B2013 Figure 3b.

7) Section 4 Discussion. I found this section far too speculative, hand-waving and non-scientific. The first part is a qualitative overview of subglacial water flow theory. The arguments for why water may be present in the canyon are OK, in general although the discussion of enhanced GHF was a bit muddled and unclear. It could have all been stated in half the space as basal frictional heating, warmer ice at depth are all well established concepts.

This section on water flow and geothermal heat flux can be made more concise. The overview on subglacial water theory is necessary to address the key issue of the paper on whether water flow within the valley is likely to be in the form of a subglacial river.

By page 7, l9 the discussion becomes too speculative.

Given the possible large extension of the valley catchment to Basin we think it is important to discuss this in this section. We try to make it clear in the discussion where we are uncertain.

The authors appear to be unaware that B2013 examined hydraulic potentials for the isostatically compensated bed (Fig 3A) and discuss this in some detail. In addition, the authors do not explain how 300-800 m of bedrock erosion from subglacial water flow is possible during the Holocene. That would be a challenge even for rapid basal sliding over a soft bed, neither of which is the case here. At LGM, ice flow and hydraulic routing was different due to larger ice sheet cover.

The overall erosive history of this valley is likely to be complicated and difficult or impossible to determine. Our results are focused on whether the present day form, in terms of it's path (in relation to ice surface slope) and along valley base slope, is compatible with a subglacial river under a thick

ice sheet. At LGM the hydraulic routing according to B2013 Fig 3b still indicates the valley roughly following the hydrological divide in the interior, suggesting that conditions for along valley water routing there could have been still been favourable then. The possibility remains that the present day valley form developed as a consequence of erosion under some or all of the following 1) under current conditions, 2) under LGM conditions, 3) during ice sheet retreat, 4) under reduced ice sheet cover, and 5) under ice free conditions. We simply do not have enough information. Tunnel valleys provide one demonstration of how subglacial water erosion can erode into hundreds of metres of bedrock. Given that the source is close to a proposed geothermal warm spot, past episodic subglacial down-valley discharges are a possibility. Much smaller amounts of erosion and deposition would be needed to maintain a base slope favourable for water routing, as is typical of rivers in general.

P7, l27. Why?

The concept here is that it seems unlikely that, in the absence of subglacial river erosion, a river formed when there was no ice sheet would take a form that would end up also being favourable for subglacial water flow under thick ice. In this sense the substantial changes to the form of the bedrock caused by the build up of km thick ice should make a roughly level paleo river valley capable of routing subglacial water all the way out from the interior, unlikely. Having said that the valley base does not appear to be perfectly level by any means, and does not follow the hydrological divide perfectly so we will need to clarify these points in the discussion.

9) P7, l30-32. This appears to demonstrate a complete lack of understanding of how the lithosphere responds to changes in ice loading. Why would there be a differential viscous response of the mantle across a < 10 km wide channel? In addition, how flat is the canyon and how flat is it after isostatic compensation? This is really incoherent.

We are referring to the along-valley differential viscous response, not the across valley one. A present day relatively level valley base over such a long distance is consistent with subglacial erosive and depositional water activity but does not prove it. The isostatic correction in B2013 Fig. S5 implies that on an ice-free Greenland the valley would be 600 m higher than present in the interior progressing to 200 metres higher near the coast. Today the valley base appears to be consistently between -300 and -500 metres with no clear trend along-valley.

10) Section 5. As for the abstract, title and Discussion, this section needs to be rewritten, focusing on the actual results and not wild and unsupported speculation.

We hope that our responses address some of your concerns and are ready to make changes where issues have been raised.

We would prefer to keep the original title after considering the following points:

- The article is about the “possibility of a long subglacial river” and as such presents evidence for such a system while recognizing that the huge void in data precludes a conclusive result.
- The word “river” is appropriate when defined as “subglacial river” which has different properties to a river over open land. In addition, many “rivers” on Earth do not flow at all times, or flow at certain times only along certain sections.

References

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