Review of Dochartaigh et al., “Groundwater / meltwater interaction in proglacial aquifers”

Although there is growing recognition of the importance of groundwater in glacierized watersheds, there have been relatively few studies that directly characterize groundwater in such systems. This study serves to help fill that gap by using groundwater wells and isotope data to quantify groundwater storage, groundwater discharge, and the contribution of glacial meltwater to groundwater. While on their own, these methods are relatively straightforward, applying them in glacierized, mountainous settings can be challenging, and thus their findings about meltwater-groundwater interactions is a valuable contribution to our understanding of glacierized watersheds. This manuscript is overall well-written.

There are some aspects of the presentation that need clarification, however.

1. Clarify “meltwater”. Ultimately, I believe the authors use the term “meltwater” to refer to glacier melt (not snowmelt), and they assume the river water consists of glacier melt. This was confusing, however. First of all, there are some references to “snowmelt”, so I was unsure at times whether “meltwater” should also include “snowmelt”. Also, the authors at times discuss groundwater/meltwater interactions after presenting results about river water-groundwater interactions, and it was not obvious that the reader is supposed to assume the river water and meltwater are treated as being the same (I pointed out specific lines below). I suggest the following. Be explicit about glacier meltwater (which could include snowmelt on the ice?) vs. local snowmelt. Also, be explicit about the assumption that the river water is glacier melt. However, I would caution against treating river water and meltwater as interchangeable, because the authors point out that the river water can consist of groundwater (during the wet season in middle elevations and all year in the lower elevations).

2. Clarify the isotope mixing model implementation. The methods section describes taking winter and summer water samples for isotope analysis, but no seasons are identified in the results. Isotope values can be very seasonally dependent – was this taken into account for the mixing model implementation? Also, what isotope value was used for the precip end-member? Was it the range of values indicated on Fig. 4 for precip at sea level? How well does isotopic value for precip at sea level apply to local precip on the mountain slope? Finally, and most importantly: why is the mixing model applied to estimate river contributions to groundwater in the middle and lower elevations (this is what Fig. 4c appears to show)? This contradicts elsewhere in the manuscript that describes flow to occur from groundwater to the river during the wet season in mid-elevations, and at all times in lower elevations.

3. Clarify the interpretation of comparing groundwater discharge to stream discharge. Your wording seems to imply that the groundwater discharge is all from glacier meltwater (even though it also includes recharge from local precip), and that stream discharge is all glacier meltwater (even though lower sections include groundwater). Perhaps this is not what is intended, but, for example, point 2 in the Conclusions makes it sound like the 0.19 m3/s groundwater discharge is meltwater. And the abstract mentions “meltwater river flow”, implying that the river only consists of (glacier?) meltwater. I suggest rewording.

4. Clarify aquifer width. Explain the assumption of 1 km width – this is a strong assumption that controls your ultimate groundwater discharge estimate. Can you explain it – is it b/c it is the approximate width of the watershed, and you assume the groundwater-shed is similar? When you report your groundwater discharge result, you should be careful to note the uncertainty due to assuming this width.

Other minor comments:
- p. 1, Line 21-23: These two sentences are confusing. I think the first sentence sets up the reader to expect that groundwater is mainly fed by local precip. The second line could be edited to better emphasize that glacial meltwater is even more important than precip inputs at certain places. Part of the confusion for me in the second line is that it was not evident that the river water is all meltwater, and so I did not realize that "groundwater / meltwater exchange" is actually groundwater /river water exchange, where river water is meltwater.

- would "groundwater-meltwater" be better than "groundwater/meltwater"?

- p.1, Line 25: be explicit that "meltwater" here is "glacier meltwater"

- p. 2, Lines 8-20. I have a few other suggestions for your lit review. Also examining a direct link between meltwater and groundwater, Saberi et al. 2019 used a watershed model to show that groundwater discharge increases by 20% with meltwater contributions in a glacierized watershed in Ecuador. Harrington et al. 2018 found that 100% of winter streamflow originates from gw (rock glacier spring discharge) in the Canadian Rockies. Baraer et al. 2015 is a nice summary paper about groundwater contributions to discharge in multiple glacierized watersheds in Peru. Also, you cite Hood et al. 2006, but you did not mention catchments in the Canadian Rockies.

References:

Baraer, M., Mckenzie, J., Mark, B. G., Gordon, R., Bury, J., Condom, T., … Fortner, S. K. (2015). Contribution of groundwater to the outflow from ungauged glacierized catchments: A multi-site study in the tropical Cordillera Blanca, Peru. Hydrological Processes, 29(11), 2561–2581. https://doi.org/10.1002/hyp.10386

Harrington, J. S., Mozil, A., Hayashi, M., & Bentley, L. R. (2018). Groundwater flow and storage processes in an inactive rock glacier. Hydrological Processes, 32(20), 3070–3088. https://doi.org/10.1002/hyp.13248

Saberi, L., McLaughlin, R. T., Ng, G.-H. C., La Frenierre, J., Wickert, A. D., Baraer, M., … Mark, B. G. (2019). Multi-scale temporal variability in meltwater contributions in a tropical glacierized watershed. Hydrology and Earth System Sciences, 23(1), 405–425. https://doi.org/10.5194/hess-23-405-2019

- p. 2, Line 25: delete comma after "revealing"

- p. 3, Line 5: specify "m.a.s.l." You specify this elsewhere, so be consistent.

- Fig. 1: helpful to be explicit in caption that your abbrevations are for Upper (U1-U2), Middle (M1-M3), and Lower (L1-L3).

- p. 3, Line 19: would be good to clarify that "meltwater" is glacier meltwater0

- p. 3, Line 26: typo ";,"

- p. 4, Line 12: comment on use of Jacob time-drawdown method for unconfined aquifer? (If not in main text, then in supplementary info?)

- p. 4, Line 29: write out “BGS” in the first occurrence

- p. 5, Line 5: change “Groundwater flow” to “groundwater discharge”

-p. 5, Line 11: why was porosity not measured directly?

-p. 6, Line 13: “compacted” instead of “compaction”

-p. 7, Line 2: confusing to see “meltwater/groundwater interactions” here. You need to explicitly explain that you assume the river water to be meltwater.

-p. 7, Line 2: confusing to see “piezometric gradients are from river to aquifer”. Flow is along negative gradient, so this phrase technically means that flow is from aquifer to river (I think you mean the opposite).

- Figure 3:
    - improve resolution
    - (a) and (b) needs legend
    - (d) y-axis label is confusing, why "and rainfall"? I believe all lines are "deviation from long term mean"
    - (d) color-code by precip vs. river impact groups? Would be easier to see what is described in text

-p. 7, Line 13: M1 is also very close to river. Any idea why it did not show up in 2nd pattern?

- Figure 4: Similar to comment for Fig. 3: I suggest color-coding to emphasize correspondence with main sources. Also, why does legend say "L3" after "All Springs"? Other figures show springs scattered, not just by L3.

- p. 8, Line 10: be explicit here that “meltwater” is assumed to be same as river water.