The Cryosphere Discuss.,
https://doi.org/10.5194/tc-2019-172-RC1, 2019

The Cryosphere Discussions

Interactive comment on "The influence of water percolation through crevasses on the thermal regime of Himalayan mountain glaciers" *by* Adrien Gilbert et al.

Anonymous Referee #1

Received and published: 9 September 2019

General comments

I think this is an interesting paper that would be interest to readers of The Cryosphere. It does a good job at making the case that mountain glacier thermal structure is plausibly influenced by crevasse distribution and deep meltwater percolation. The overall quality of the scientific work appears to be good, although I called out several questions and concerns about both the methods and the reproducibility below. I don't think any problems that I bring up are necessarily fundamental to the study and uncorrectable.

The figures are very nice. As a general suggestion, I would recommend choosing colourmaps that are likely to be better preserved in print form (i.e., the "jet" colourmap

is virtually useless in black and white).

Regarding presentation, I've made a few suggestions that I think might improve the comprehensibility of the paper. I also recommend a thorough language-proofing.

Specific comments

Much of the argument relies on the correlation between observed surface crevassing and radar scattering, similar to what has been previously linked to englacial temperate ice. An alternate hypothesis might be that surface crevassing causes the scattering the radar signal, which I think should be discussed. Is it possible to discount this based on the timing of the scatter in the radargrams (or by some other means)? If so, I think it would strengthen the paper's argument to do so.

I also found some of the description of the procedure used to model the firn thickness and enthalpy distribution a little hard to follow, and a less ambiguous format (such as pseudocode) would help. Some of the equations seem to use undefined or non-canonical values.

What work has been undertaken to demonstrate the numerical validity of the procedures described in sections 3.3 and 3.4? (It's possible that a reference could be provided for 3.3, if prior art exists.) I found section 3.4 particularly hard to follow. It might be nice to structure in the form of a list of assumptions that are being made to put the existing derivations in context. A diagram demonstrating the geometry of the problem would also help.

On a similar note, will any of the modelling code be made available, similar to the radar data? I feel that doing so would go a long way to improving the reproducibility/auditability of this paper and the included methods (and code is so easy to distribute now that it would be wonderful to do so).

Technical corrections

(grammatical suggestions annotated as "(gr)")

16: (gr) "In cold and arid climates"

18: How does GPR reveal temperate ice? Is it more correct to say that GPR suggests/implies temperate ice due to bed reflectivity measurements?

21: (gr) "Model experiments show"

23: (gr) "The time scale of thermal regime change"

25: (gr) "without the effect of the crevasses"

41: (gr) provide direct observations of the glaciers' thermal condition

42: (gr) gives only

48: s/localization/location

51: (gr) "two previous"?

56: no semi-colon

59: (gr) "to draw conclusions"?

65: (gr) capitalize "Valley"

67: (gr) "in the vicinity"

71: Can any additional information be provided about the type of antenna and transmitter used? How wide is the frequency band over which energy is produced? Is this a frequency domain or impulse-type system?

73: Could you clarify whether all reflectors were picked, or only the one thought to represent the glacier base?

82: What's the spatial resolution of this imagery and of the DEM produced?

86: Perhaps the model variogram parameters could be shared in an appendix?

95: (gr) "greater than what could be supported by ice deformation alone and thus

implies basal sliding"

103: I'm not sure that I understand "are calibrated ... by linear regression method" well enough that I could reproduce this independently given the data. Could you describe in greater detail (or if this is done elsewhere, provide a reference)?

eq1: do we constrain R as less than to equal to M, or is it possible for refreezing to exceed melting (either locally or over the entire domain)?

125: I don't think the description for $r_\text{s/m}$ is correct. As written, one would expect that it could never exceed 1, however in eq4 it's clear that it can (i.e. in the accumulation zone). Perhaps it would be better described as "the ratio of annual accumulation to melt"?

eq3: Doesn't the second case imply that if the annual accumulation is half the melt, we model the radiative melt factor as if the surface we ice-covered half the time? It's not obvious to me that this should be true.

eq5: Since this is an annual precipitation rate summed over 365 days, don't we need to divide by 365 somewhere? I also find the units given for dP/dz surprising - I would have expected it to be m w.e. / (a m) to match Pref.

144: Is this parameterized in any way? Coefficients or parameterizations used in the flow law should be described.

153: (gr) "well-constrained,"

eq8: It'd be nice to drop the parentheses around T to disambiguate it from function application (as it's used on the LHS and in one of the integration limits). Also, I'm not sure we've defined $T_m(P)$ yet.

171: can this assumption (crevasses go to the bedrock) be justified?

184: I think this section would benefit from a listing with pseudocode explaining the various steps here. From how I understand it, you're doing somthing like

1. start with initial temperature T 2. compute strain rate edot from T (KP2010, equation not given) 3. compute initial Qlat with eq10 4. compute H from the edot and Qlat with eq7 assuming dh/dt is zero 5. compute T from H with eq8 and goto 2

197: Does the grid move with the surface or is it fixed?

202: (gr)

209: Can we simplify eq12 by expressing df in aˆ-1 (to avoid the scaling parameter)?

215: In equation 14, should F be Fref?

216: The notation might be a bit muddled here - the function is parameterized by zf (undefined, I think?), but that doesn't appear on the RHS. A diagram might help.

225: I'm pretty sure the units don't work out here - c(t) is accumulation per day, but df.F is per second

226: Again, I think a more structured way of describing the algorithm, like a simplified code listing, would be helpful; the text feels too ambiguous.

234: "shifted our temperature forcing" - how and how much? (If this is described later, I had a hard time making the connection.)

236: I'm not quite sure at first what "reported to the bedrock topography" means; are you altering the bedrock by an amount equal to the free surface change? Later in the paper I gather that you also changed the bedrock significantly in places where there is ground truth, which I think deserves justification.

246: "reasonable accordance with the observation" - what exactly does this mean, and what are the criteria for "reasonable"? And do we even expect the observations to be similar to the steady state?

261: How do we know that scattering isn't due to the crevassing itself?

287: s/inexistent/nonexistent

325: (gr) not a complete sentence

339: I presume this means "no snow or firn over the surveyed part of the glacier," as there does seem to be a large part of the glacier above the ELA where we might expect firn?

340: What are the uncertainties in the surface DEM? Are they meaningful (i.e., they're used as an input to create the modelled bedrock topography, IIUC)?

346: It's interesting that these uncertainties are much smaller than the differences between the measured is thickness and the modelled ice thickness, and it's hard to believe that 20 m of horizontal uncertainty account for the rest. Any idea where the remaining difference could come from? Is it all from the assumed friction parameter?

356: s/delicate/difficult

359: I might be misinterpretting this statement, but I'm not sure I agree; the advection of heat should depend on whether motion is at the surface or distributed throughout the thickness, shouldn't it?

Figure 1: This should list the UTM zone in (b). Can we also add the glacier outline to (b) as in Figure 3?

Figure 2: Is it possible to demarcate the (approximate) extent of the surface crevasses? (the labels don't do a very good job of indicating how wide the crevassed area is)

Figure 3: The panes would be more comparable if they used the same colour scale (i.e. currently one is [0, 150] m and the other is [0, 200] m)

582: s/localization/locations

588: s/localization/location

Figure 8: difficult to distinguish between modelled background and observed dots In figs 8,9, would be helpful to label the columns (i.e. no percolation, with observed

crevasses, with modelled crevasses)

Figure 10: Again, the modelled vs measured points in the map are difficult to distinguish

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