

## Review Gilbert et al

The manuscript *The influence of water percolation through crevasses on the thermal regime of Himalayan mountain glaciers* by Gilbert and others is a very nice study on the polythermal regime of mountain glaciers. The paper describes a good modeling study that can explain the observed interesting polythermal structure.

Nevertheless, a lot of small changes are needed to render the manuscript ready for publication. Obviously, we as non-native English “users” have a big disadvantage, and our formulations might be not idiomatic. Despite this, care should be taken to at least consistently use “the”, (the apparently random) capitalization rules, proper words (“localization” instead of “position” or “area”, English – if somewhat similar – is not some kind of French), etc.

Once the many below concerns have been addressed (and many more which I did not all mention, since this is more time consuming than just rewriting the text), the paper will be ready for publication.

Sincerely, Martin Lüthi

### General comments

Overall, this is a very nice paper on an important topic. The modeling study is nicely crafted, comes to meaningful results, and elucidates some very relevant processes in polythermal glaciers. What I really liked is

- good and comprehensive Introduction,
- very good and thorough approach to the problem at hand,
- very nice modeling study to explain noteworthy features in a unique data set,
- good, meaningful Discussion of the important processes and their general significance.

This being said, the paper unfortunately is presented with many small warts that should be cured before it is ready for publication.

It took me unusually long to write this review, especially since I commented on many small things that should have been improved by the proof-readers before submitting the manuscript. Using colons (:) before equations, citing equations without parentheses around equation numbers, using  $\times$  for multiplication in formulas etc. are things I have never seen in any of the usual journals. Please adapt to the conventions of the journal. Also, the paper would certainly profit from streamlining by a native speaker (I only indicated a few (many!) small issues).

In the Methods section care should be taken to clearly describe the algorithms used, especially these rather ad-hoc rules that describe meltwater percolation. Especially section 3.3 is very opaque, and would profit from a flow diagram or a formula describing the iterations (I think).

Also the algorithm in Section 3.4.2 is not easily understood, and details on the procedure are missing in some steps (e.g. Step 2).

Some formulas (e.g. Eq. 14) appear to contain errors (outlined below).

Some figures, and many figure captions should be adapted and improved.

My feeling is, that the main results could be explained with less figures, and some of them could be moved to an appendix / supporting material section.

The bibliography appears complete with DOIs (although given as URL). ISBN/ISSN should be given for the cited books.

### Specific comments

41 “the small number of boreholes gives ...”

43 “extrapolated”. The whole sentence is somewhat awkward, better reformulate and split in two.

45 “Scattering of electromagnetic waves ...”

46 start new sentence after “GPR data”.

47 also Ryser et al. (2013) nicely showed the relation between ice temperature and scattering.

50 “rare” instead of “rearer”

74 or  $168 \text{ m } \mu\text{s}^{-1}$

84 better “imagery”

86 “the Kriging algoritm” (give reference).

92 and 94: “stake” (singular)

95 “support” seems wrong here, better use “can be explained”. And then, one wonders which ice flow parameters and stress regime have been used to arrive at this conclusion.

96 Since ice temperature is the main focus of this study, one is curious about the measurement process. Were the holes drilled mechanically or thermally? Was temperature measured once, or logged? Type of sensors and measurement equipment would also merit description.

100 “as input data” (leave away “an”)

104 leave away “method”

106 “aims at identifying”

106 “observed”: better say “deduced from“

107 no comma after “which”

112 leave away the colon (here, and before all equations). TC does not use this style.

115 only give units once (they have to be the same anyway).

117 this contradicts line 111. Only say you used and improved model there.

118 How does short-wave radiation affect ice dynamics (leave away)?

- 125 from where do you know the  $f_{rad}$  values?
- 142 what value do all these factors have? Are they taken from literature, or determined from local measurements?
- 151 Using  $Q$  for a source term is unfortunate notation, since often  $Q$  denotes fluxes. Indeed, it is called a flux on line 174.
- 152  $\sigma$  and  $\varepsilon$  should also be written bold in the text
- 153 “constrained”
- 155 replace “defined” by “written in terms of”
- 159 A dot is missing in the number  $3 \cdot 10^3$
- 162 Here it would be interesting to say what the vertical resolution in meters is.
- 162 What kinds of elements have been used? Geometry and approximation order should be mentioned here.
- 171 Why and how is water percolating to the bed? Ice (even temperate ice) is pretty impermeable.
- 173 “neglected”? Not clear what you want to say with this. Neglected from what?
- 174 Why a heat flux, and in which direction? This should be a source term in Equation (7).
- 175 How is the amount of refreezing water determined?
- 179 Top to bottom of what? Of the glacier or of the layer?
- 180 “fusion of water” is, I think, simply  $T_m$ .
- 180 “the water can access”
- 184 I don’t think  $Q_{lat}$  is a flux. It’s a source term.
- 185 This whole description of the algorithm is somewhat opaque. Please consider a flow diagram, or a clear description of what happens.
- 186 “steady state”: what are you doing here? Do you mean you do a fixed-point iteration until convergence? Are the steps iterative steps (for the solution at one grid point), or time steps? I doubt that you calculate a steady state of the whole glacier here.
- 191 “distribute”: I think you use the 1-d model at every grid point, independent of all other grid points? If so, please say that.
- 193 “for the 3D model”
- 194 “It provides a high ...”
- 200 how sensitive is the temperature profile to the choice of the Gaussian standard deviation?
- 203 “reaches”

- 209 why not just using a commensurate value  $d$  with time unit in years<sup>-1</sup>, then  $t_{yr}$  could be left away.
- 217 “Combining Equations (13) and (14) gives” with parentheses around equations, “Equations” capitalized, and the sentence without colons (like any other article in TC).
- 222 The time step should be named  $\Delta t$  (not the infinitesimal  $dt$ ), and already named in the text.
- 227 why is “Topography” capitalized. Even if English has no meaningful rules, titles should be capitalized consistently.
- 229 “known” instead of “resolved”
- 233 ”the” instead of “our”
- 234 leave away parentheses around  $\beta$ .
- 235 Was this “best” determined with an optimization?
- 235 What is the meaning of these units?
- 236 What is done during the “reporting”? This is probably not the right expression, and something happens to update the bed topography.
- 239 “constraining with”?
- 246 “observations”.
- 246 “permits” instead of “allows”
- 249 “were performed” (also the past/present tense should be used consistently)
- 256 I’m not sure whether a comparison to other glaciers would rather belong to the Discussion.
- 260 Why not simply “that the occurrence of temperate ice ...”
- 264 Reference needed for ERA.
- 269 “equilibrium line altitude” (lowercase)
- 271 “provides” sounds wrong, why not “the model is in good agreement with ...”
- 287 “in areas without radar measurements”
- 303 weird sentence, please correct
- 308 “in equilibrium”
- 310 “the climate change” is pretty meaningless. Probably you mean “surface warming” or similar? Also line 317.
- 312 please call this consistently “ERA-interim”. The time series should also be shown, maybe in Figure 4c.
- 320 “crevasses”

- 321 “linearly increasing temperature”, the trend is not increasing.
- 325 Do you mean polythermal glaciers in general. Then the “the” should be discarded.
- 326 this sentence is incomplete.
- 331 weird sentence
- 336 weird sentence
- 337 “values”. Better rephrase
- 338 “calibrated on data” is not proper English (IMHO)
- 340 A GPS (Garmin) should be accurate to 5-10 meters, so what is the problem here?
- 344 Considering how much effort it is doing these measurements, why don’t you use some cheap real-time corrected GPS, such as the Emlid Reach?
- 352 “the friction ...”
- 355 complicated sentence, rephrase
- 355 Why is this “mass flux conservation” special? It is part of the solution of the Stokes equations.
- 362 “coming from”: better “derived from surface melt”
- 368 “the Greenland ...”
- 370 “the thermal regime”
- 372 not really “observed”, but “inferred for”
- 384 “position” instead of “localization”
- 385 “warming” instead of “climate change” (which is a generic catch phrase without any particular meaning for this mountain area – there could also be local cooling)
- 392 “combined”
- 393 “reveals”
- 394 “crevassed areas” or “crevasse fields”
- 395 “facilitates/permits/enables” instead of “allows”
- 396 “affects”
- 397 “the thermal...”
- 398 “surface temperature increase” or “surface warming” (again, climate change is un-specific)
- Eq 5 Why are you using % and (1/100) here? Its easier to understand if you just use the ratios.
- Eq 12 write equations without “×” (also in many others)

- Eq 14 the integration variable should be  $dz$ , not  $dz_f$ . Maybe the upper integration limit should be  $z_f$ . This should be written carefully!
- Eq 16 Do not use  $\times$  in any of these formulas, they become unreadable.
- Fig 1 (a) The black line around the glacier is barely visible, use orange?  
 (b) Could the location of the thermistor chain be indicated with something more distinctive, e.g. a red diamond.
- Fig 2 The caption should also mention what we see, i.e. cold and temperate zones (with and without reflections). An approximate distance and depth scale should also be given. Microseconds could be used instead of 1000s of nanoseconds.
- Fig 3a The black dashed line is really hard to see. This line should also be explained in the caption. It is also quite unfortunate to use different depth scales in the panels.
- Fig 4 caption (585) please use correct English for plural: “stake positions” / “stake measurements”
- Fig 5 caption (588) “at the three stake positions” (we already know that they are different)
- Fig 5 caption (589) What does “steady” mean in this context of an oscillating forcing? Is this a limiting cycle (stationary periodic response at depth)?
- Fig 6 caption: “localization”: better say “positions”
- Fig 7 panels (a) and (c): the half-transparent colors of the plot are different from those of the color bar. Use the full colors ( $\alpha=1$ ). This also applies to other figures (9-12).
- Fig 7 caption: “localization”: better say “crevassed areas”
- Fig 8 upper panels: “temperate” in lower case on both axes
- Fig 8 lower panels: the dots are very difficult to see. Maybe a white border around them would help?
- Fig 8 a minor detail, but why are panel letters not placed as in Figure 6, 7 and 9?
- Fig 9 Could the temperate basal areas be shown by a red color? In this color scheme the changes are too gradual for this very important switch. Are the temperatures here absolute, or relative to the pressure melting point (which is the only meaningful quantity to show here)?
- Fig 10 caption (609): “the ablation zone”
- Fig 11 caption (616): these are longitudinal sections (along flow line), not cross sections (across ice flow). Also correct this in all captions and the main text.
- Tab 1 proper notation uses a central dot, not a cross ( $5 \cdot 10^7$ , not  $5 \times 10^7$ )
- Tab 2 “Precipitation Lapse rate”: consistent capitalization! Also the units are weird, why not just  $\text{m}^{-1}$  (although I think this should be  $\text{a}^{-1}$ , so this is completely wrong).
- Tab 2 Are the radiative rates per square meter? So the units are wrong.

## References

- Ryser, C., Lüthi, M., Blindow, N., Suckro, S., Funk, M., and Bauder, A. (2013). Cold ice in the ablation zone: its relation to glacier hydrology and ice water content. *Journal of Geophysical Research*, 118(F02006):693–705.