The Cryosphere Discussions

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Comment on tc-2022-119

Anonymous Referee #1

Referee comment on "Physical Experiments on the Development of an Ice Tunnel from an Upstream Water Reservoir through Simulated Glacier Dam" by Chengbin Zou et al., The Cryosphere Discuss., https://doi.org/10.5194/tc-2022-119-RC1, 2022

The paper describes a laboratory experiment for an ice-dammed glacier lake drainage. The setup is in a flume where a 0.5m wide ice block dams the upper part of the flume which thus forms a reservoir with a volume of about 1m3 of water. Of note is that very warm water of 12C to 25C is used in the experiments. A initial channel within the ice block is prepared with the help of a frozen-in tube. At the start of the experiment this tube is removed and the reservoir drains thought the ice channel. At first flow is pressurised (the authors call this "surcharged", a term from wastewater engineering which is not used in glaciology) but as the experiment proceeds free surface flow establishes. Water flow speed in the entry-region of the channel and stage in the reservoir are measured, additionally they authors take an imprint of the final state of the channel with foam. They infer drainage characteristics such as hydraulic head and friction.

Whilst the study is interesting and novel, unfortunately, the manuscript suffers from many shortcomings and thus the findings are not supported as the manuscript currently stands. It is not clear to me, whether these shortcomings can be rectified with the available dataset or whether the study needs to be re-done from the ground up.

Major shortcomings

There are a few previous laboratory experiments of water flow through ice channels in a glaciological context. They need to be stated and cited in the introduction. To mind comes Isenko et al 2005 (https://doi.org/10.1016/j.coldregions.2004.12.003) and Pohle et al 2022 (https://doi.org/10.1017/jog.2022.4, that was actually a field experiment but similar in spirit nonetheless). Probably good to search in the literature citing Isenko et al on any other relevant laboratory studies.

There are quite a few issues around hydraulics in the manuscript:

- The often cited Barr (1891) manuscript merely solves the Colebrook-White equation (eq 7 in the manuscript), which is an empirical relation between the Darcy-Weisbach friction factor, the hydraulic diameter and the (Nikuradse) equivalent sand roughness. It is trivial to numerically solve the Colebrook-White equation so no need to cite Barr. Nor did he propose any "pipeflow equations" as stated in the Abstract.
- In glaciology, hydraulic roughnesses of englacial channels are typically stated using Manning's roughness n' or the Darcy-Weisbach friction factor f. The Nikuradse equivalent sand roughness is, as far as I know, never used. Thus the authors should probably just state their results in terms of n' or f, and discuss in terms of shape and form roughness. By the way, a nice recent paper on scalloping is Bushuk et al 2019 (doi: 10.1017/jfm.2019.398). Another good citation on hydraulic roughness is Chen et al 2018 (doi: 10.1029/2018GL079590). Both should be mentioned and discussed.
- On line 259, the authors state that 2/3 of frictional heat is available for melt. This is correct but out of context, as the context is that 99.99% of melting is due to the heat contained in the warm water. The ratio of potential to thermal energy is 9.81 * h / (4100 * T) which is for this case ~ 1e-5 (h=0.5m, T=25C).
- The calculation of the hydraulic gradient (energy slope) does not make sense to me. They use the Colebrook-White equation with the measured discharge and some random assumption on the sand-roughness and then calculate the hydraulic gradient. I don't see the value of this calculation as it just assumes some random sand-roughness and produces an equally random hydraulic gradient.
- There will be quite some inflow resistance from the reservoir into the channel resulting in a pronounced hydraulic head drop. This would need to be taken into account in any serious calculation. (note that in the case of real lakes that is not necessary as the channel is relatively much longer)

Equations 1-4 are incomprehensible to me. Variables Q1, Q0, t1, t0 are undefined. The main equation, as is stated by the authors, is indeed Q = -dS/dt, where Q is the outflow discharge and S is the reservoir volume. Now S=h A, where h is the stage (measured continuously by the authors) and A the surface area of the reservoir (essentially constant in this case). Thus Q = - A dh/dt, where a little care needs to be taken in evaluating `dh/dt` from the measurements as noise is amplified during numerical differentiation: i.e. use a smoothed h-time-series.

The authors use two ways to infer the cross-sectional area: (1) dividing measured discharge by measured flow speed, and (2) from the foam imprints taken at the end of an experiment. These measurements are never compared. Also, from eye-balling the figures they seem to be vastly different: for two similar experiments (1) gives around 0.06m2 (Fig 6, 25C at 70 seconds) whereas (2) gives 0.01m2 (table 1, 23C at 102 seconds). If anything the latter should be bigger as it is both the water-filled and air-filled cross-section. The authors need to show a detailed comparison of the two ways to calculate the cross-sectional area.

The authors state the cross-sectional are (according to method (1) from above) increases from approx. 10^-4 m2 to 10^-2 m2 within a few seconds (line 261 & 300) --a 100-fold

increase-- then stays more or less constant (less than 5-fold increase) throughout the rest of the experiment. This seems very implausible to me. I suspect that this has to do with their velocity measurements. If it is indeed correct, this needs better support and in-depth discussion.

The description of the experiments is severely lacking. For instance it is not clear to me how many experiments were conducted. The experiments need to be described, labelled and also presented in a table; this warrants its own subsection in Methods. Further, the authors talk about "perturbed" and "unperturbed" experiments (see line 139) but it is not clear at all what this means.

There are no scientific insights gained from fitting a 4th-order polynomial to part of the cross-sectional area. Much less stating an R^2 value for the goodness of the fit.

Last, note that I did not study the Discussion in-depth as the limitations of the methods render, in my opinion, the results untrustworthy and thus also the discussion.

Smaller comments

Terminology needs to be consistent. In particular I noticed that the channel is described with the words "tunnel", "tube" and "conduit". Just one word should be used as anything else is confusing. Similarly with "energy gradient", "energy slope" and "hydraulic gradient".

The picture in figure 1 is, as far as I can tell copyrighted (it says "© 2022 All rights reserved" at the bottom of the linked web-page). One cannot just take random pictures from the internet and use them. Either remove that picture or get permission from the copyright holders or state a license if usage is indeed allowed.

When citations are not exhaustive then an "e.g." should be used. For instance on line 39. Many instances.

The water used in the experiments is very warm, up to 25C. This is far warmer than the water of glacier lakes which is more commonly around 1C, or maybe 10C for water heated by volcanic activity. Water can easily be cooled using, for instance, crushed ice.

Section 3.1 and 3.2 are verbatim copies of each other, except with different numerical values. That is not okay. Can be made much more succinct.

Section 3.4: the values in the text do not correspond to the values in table 1.

Line by line comments (by far not exhaustive)

Title: I'd use "Laboratory experiments...", as field experiments are "physical" too.

9 & 32: no, the simulated lake is not "proglacial" but "ice dammed". Proglacial lakes are typically moraine-dammed and not ice-dammed (there is typically no ice in front of the glacier).

24: "surcharged" is not used in the glaciological literature. Use "pressurised flow".

27: "Once free surface flow occurs..."

19: "as" -> "and"

53: also cite Flowers et al 2004 (https://doi.org/10.1029/2003GL019088)

62: "increase" -> "decrease"

65: cite also Clarke 2003

168-170: is the melt now included or not? Needs to be stated clearly.

175: for the gradient, also a division by the length is needed.

191: "invert" -> "inlet"