The Cryosphere Discuss.,
https://doi.org/10.5194/tc-2019-138-RC2, 2019

The Cryosphere Discussions
Open Access
EGU

Interactive comment on "An analysis of instabilities and limit cycles in glacier-dammed reservoirs" *by* Christian Schoof

Mauro Werder (Referee)

werder@vaw.baug.ethz.ch

Received and published: 17 September 2019

This paper investigates the mathematical properties of a conduit model (R-channel + one linked-cavity) when the upper boundary condition is a reservoir of fixed surface area and recharge rate. It looks at reservoir sizes corresponding a range from large glacier dammed lakes to moulins. It finds that for a given reservoir size that there are two stable regimes: one when the reservoir drains through the linked-cavity (i.e. recharge is low) and the other, when recharge is high, it drains through a moulin-like configuration. In-between the reservoir drainage is unstable and in fact periodic (for most situations), i.e. lake outburst floods.

I think the paper nicely illustrates and investigates the range of behaviours to be ex-

Printer-friendly version

Discussion paper

pected from ice dammed reservoirs. Whilst this range of behaviours (leaking lake, outbursting lake, and moulin-like) has been known, it has not yet been described quantitatively; certainly not with this mathematical rigour. Thus this paper is a significant step forward.

However, the paper is a bit on the technical side for a glaciological paper. This is nicely illustrated by the brutal subsection of the Discussion (Sec 5.2), where the un-expecting reader – suffering from formula-overload already – is again presented with a wall of maths. And all this "discussion" does not actually lead to any further notable points of Discussion.

I recommend to publish this MS after Sec 5.2 has been banned to the supplement (or another publication) and the comments detailed below are addressed.

Scientific comments

The different triggering mechanism should probably be discussed a bit further. Of interest is in particular that many lakes drain with different triggering mechanisms from outburst to outburst (e.g. Grimsvötn 1996 vs other years, Gorner Lake (Huss et al., 2007)). In the case of Gorner Lake, no observations can predict the triggering mechanism.

Further, Huss et al. (2007) also show that Gorner Lake can indeed leak before drainage. This should be mentioned alongside Fisher (1973).

The paper by Kessler and Anderson (2004) should be discussed further, both in the Introduction and Discussion as it uses also a conduit model (linked-cavity + R-channel) and applies it to a lake drainage (their section 4.2). For instance, they also see the pre-drainage leakage.

The model used has a single cavity, but it could also be used with many cavities in parallel. The supp. of Schoof (2010) does this. Mention briefly what the impact would be, I suspect it would only be quantitative.

The fact that moulins are "small reservoirs" is only mentioned really late in the MS. Could/should this be mentioned earlier?

It is not clear to me why Appendix A is there but most other extra calculations are in the supplement, in particular as the more detailed calculation of Appendix A is also in the supplement.

Specific comments

Please run a spell checker over the MS!

P1, L7: delete "a"

P1, L16: mention that a lake drainage can also terminate when the lake is completely empty. This should be mentioned at a later stage as well, stating that this is not not relevant for this MS (the bed is flat).

P1, L20 write: "magnitude and timing of the flood." As for hazard prevention knowing the timing is probably equally important to the magnitude.

P2, L13: "directly directed" is awkward

Eq 1a: state that the pressure dependence of the melting point is neglected

Eq 1c: I find this equation strange. For v_o (and v_c) no separate equation $v_o = v_o(S)$ is added either. Thus be consistent and just write $q(S, \Psi)$ in Eq 1a&b. Similarly in all later equations.

P2: would it make sense to somewhere define what a "conduit", a "channel" and a "cavity" is? For example on P7,L4 "conduit" is used signalling the use of the v_o term again. So an unexpected reader may trip there without a clear definition.

P4, L5: write "background hydraulic potential"

P4, L24: "large lakes"

P4, L28: This paragraph confuses me. Is this not obvious? If not, be explicit what is

odd. If it is obvious, delete.

P5, L1: "in general"

Figure 0: A figure depicting the used geometry would be helpful.

P6, L28: "model"

P7, L21: these "reservoirs" are, e.g., moulins. Why not state this here?

P8 (on this page line numbers are messed up), L5+2: $q(\bar{S}, \bar{N})$

P8, first un-numbered Eq: this should be v_o not v_0. Or is $v_0 = v_o(S)$? If so state.

P9, L24-29: this describes again a moulin

Fig 1: replace "lake" with "reservoir"

Fig 1: parenthesis missing after "3.3"

P11, L11: again v_o

P12, L22–23: the "immediately" needs to be weakened here. According to fig. 3: lake is empty and starts filling at the point (70,10), then the lake is filling again but S still drops from 10m^2 to $\sim$0.

Fig.3: Split the second sentence at the "and"

Fig.4: could the plotted V_p be added as horizontal lines to Fig. 6?

Fig.4: I don't understand what the line style "solid dashed" is supposed to be. I think the unstable periodic should be described as "dotted coloured"

Fig.4: "insets"

Fig.5: zoom to relevant q_{in} values

Fig.6: it is not clear to me what is meant with "as well as in a small strip to the right of the right-hand branch of the red curve." nor is this intriguing strip ever mentioned in the

text. Clarify. Maybe a zoomed inset?

Eq 16: should be "$\sim$"

P19, L16: "the its", delete "the"

Fig 7: "(b), 10 km"

Fig 7: "plotted in black" needs to be more specific. "plotted as black line"

Fig. 89, P32, L5: In view of this model behaviour and the potentially unstable numerics, some words should be said about the employed numerical methods (spatial discretisation, time-stepper). Yes, the code is provided but this should be in the text.

Fig 9: What is S_R?

P23, L8: I don't see: "amplitude slowly grows" in fig 10

P25, L1: "reservoir" instead of "lake"

P26: twice wrong reference to 2012 instead of 2014

P26, L6: "results"

P26, L21: "a spatial"

P27, L11: $\mathcal{R}$ needs to be defined

P30, L5–9: remove if Sec 5.2 is removed

Supplement: Excellent, that the code is published! Two things: (1) There should be a README in each zip file, stating at least which script needs to be run to produce which figures. (2) I would suggest to add a licence to each zip-file (preferably an approved open source licence, the BSD-licence is popular with Matlab files https://opensource.org/licenses/BSD-3-Clause). Then it is clear under which conditions the code can be used.

Interactive comment on The Cryosphere Discuss., https://doi.org/10.5194/tc-2019-138, 2019.