Review of Jenson et al 2023 – Round 2

Anonymous reviewer 2

August 30, 2023

This is my second review of this manuscript (MS). This paper describes a jökulhlaup model of a brine-filled lake draining through a R-channel taking into account effects of saline water on the dynamics. It finds that the biggest impact of the salinity on R-channel dynamics is due to the increased density of the fluid.

This short paper has interesting findings and is novel as no-one has looked into impacts of salinity on R-channel dynamics.

After clarifications from the authors in the last round of reviews, I am pretty certain that the presented mathematical model of energy conservation is wrong. This needs to be fixed before a publication is possible. I suspect that the fixed model will lead to similar conclusions and that a publication is warranted.

1 Major comments

The energy conservation of R-channels is modelled with varying level of complexity:

I the more complex models take water temperature as a state variable and then resolve the heat transfer to the channel walls via some empirical relation (e.g. Nye, 1976; Fowler, 1999; Clarke, 2003). (Note that Fowler (1999) actually ignores pressure melting point effects.)

II the explicit dependence on temperature can be removed by assuming the water temperature follows the pressure melting point of the ice walls of the channel (e.g. Röthlisberger, 1972; Werder et al., 2013)

III to simplify matters further, it can be assumed that the melting point does not depend on pressure (e.g. Schoof, 2010; Hewitt, 2011; Kingslake, 2015).

Of note for this review is that (to my knowledge) all R-channel models which take pressure melting point effects into account use the water pressure to set the melting point and not the ice overburden pressure as assumed in this MS. The reason that the water pressure is used, is because the pressure felt by the ice at the channel walls is the water pressure.

The MS is aiming to make a category II model (with salinity effects added) but makes two, in my opinion, wrong choices:

- Eq. 7 states that the pressure melting term is dependent on the ice pressure P_i. Instead (as I just argued above), it should be the water pressure, i.e. the last term should read $-7.45 \times 10^{-8}(P_i - N)$ (with effective pressure N). Note that this means that the melting point and also water and ice temperature (they are all equal in a category II model) will in general change in time and space as pressure (and salinity) changes.
- Eq. 8 contains no terms related to the change in salinity and pressure along the channel.

To derive an Eq. 8-like equation, I would do the following steps. Take Eq. 2.4 of Fowler (1999) (on which the MS is based already), which using the MS's notation translates into

$$\rho_w \sigma_i (S\frac{\partial \theta_w}{\partial t} + Q\frac{\partial \theta_w}{\partial s}) = Q(\psi + \frac{\partial N}{\partial s}) - m\mathcal{L} - m\sigma_i(\theta_w - \hat{\theta}). \tag{1}$$

Now assuming a quasi steady-state $\frac{\partial \theta_w}{\partial t} = 0$ and a water temperature at pressure melting point $\theta_w = \hat{\theta}$. To simplify the algebra a little, I drop the higher-order terms of Eq. 7 (but they could be retained), Eq. 7 then reads

$$\hat{\theta}(\beta, N) = \theta_w = -6.05 \times 10^{-2}\beta - 7.45 \times 10^{-8}(P_i - N). \tag{2}$$

Now the $\frac{\partial \theta_w}{\partial s}$ term can be stated as

$$\frac{\partial \theta_w}{\partial s} = \frac{\partial \theta_w}{\partial \beta}\frac{\partial \beta}{\partial s} + \frac{\partial \theta_w}{\partial N}\frac{\partial N}{\partial s} = -6.05 \times 10^{-2}\frac{\partial \beta}{\partial s} + 7.45 \times 10^{-8}\frac{\partial N}{\partial s}. \tag{3}$$

Thus the Eq. 8-like equation reads

$$Q\left(\psi + \frac{\partial N}{\partial s}\right) + \rho_w \sigma_i Q\left(c_\beta \frac{\partial \beta}{\partial s} - c_N \frac{\partial N}{\partial s}\right) = m\mathcal{L} \tag{4}$$

with $c_\beta = 6.05 \times 10^{-2}$ and $c_N = 7.45 \times 10^{-8}$. So, for $\frac{\partial N}{\partial s} > 0$ (i.e. water pressure dropping along flow) melt m is decreased as pressure-melting point increases (see e.g. Röthlisberger (1972)); similarly for $\frac{\partial \beta}{\partial s} > 0$ melt is increased as salinity-melting point decreases. This is how I would expect the model to behave.

Last, note that the behaviour of above equation cannot be captured by the MS's Eq. 8 (even with corrected Eq. 7). I suggest to update both the MS and the numerical code to reflect above. If there is something I am missing in the approach presented in the MS, then it should be well explained as it does not follow the usual approach. (But even then, I would recommend that the MS follows the standard approach to keep it comparable to existing work.)

Also, I recommend to have both pressure-melting point and salinity-melting point effects included in the model and to look at their relative importance.

If the authors agree with this change, then Section 4.3 (in particular Eq. 16) needs to be adjusted as well (or remove the Section).

2 Line by line comments

3: "temperate ice"

4: maybe "cold glacier" the "cold-based" suggests to me that only the base of the glacier is cold

Table 1: "melting point of water and brine at pressure"

Eq.4: I think it should be m/ρ_w as the ice melted will produce fresh water.

98: "in ice as used in Fowler"

101: "(Clarke, 2003)"

111: "density due to pressure or temperature."

Eq.7: see above

118: As outlined in "Major comments", this assumption is not how things are normally setup. For instance the cited Clarke (2003) uses the standard approach of setting the ice-wall temperature dependent on pressure (his Eq. 13).

Eq.8: see above

123: should be "$\mathcal{L}$"

137: this equation does not describe a flux as flux should have units of kg/s (or m3/s). Nonetheless Eq. 9 is correct.

Eq.11: remove unnecessary brackets

326: maybe state that the conservation of energy equation is substituted into A1

359: remove extraneous bracket

367: the M is undefined

References

Clarke, G. K. C. (2003). "Hydraulics of Subglacial Outburst Floods: New Insights from the Spring–Hutter Formulation". In: *Journal of Glaciology* 49.165, pp. 299–313. DOI: 10.3189/172756503781830728.

Fowler, A. C. (1999). "Breaking the Seal at Grímsvötn, Iceland". In: *Journal of Glaciology* 45.151, pp. 506–516. DOI: 10.3189/S0022143000001362.

Hewitt, I. J. (2011). "Modelling Distributed and Channelized Subglacial Drainage: The Spacing of Channels". In: *Journal of Glaciology* 57.202, pp. 302–314. DOI: 10.3189/002214311796405951.

Kingslake, J. (2015). "Chaotic Dynamics of a Glaciohydraulic Model". In: *Journal of Glaciology* 61.227, pp. 493–502. DOI: 10.3189/2015JoG14J208.

Nye, J. F. (1976). "Water Flow in Glaciers: Jökulhlaups, Tunnels and Veins". In: *Journal of Glaciology* 17.76, pp. 181–207. DOI: 10.3189/S002214300001354X.

Röthlisberger, H. (1972). “Water Pressure in Intra– and Subglacial Channels”. In: *Journal of Glaciology* 11.62, pp. 177–203. DOI: 10.3189/S0022143000022188.
Schoof, C. (2010). “Ice-Sheet Acceleration Driven by Melt Supply Variability”. In: *Nature* 468.7325, pp. 803–806. DOI: 10.1038/nature09618.
Werder, M. A. et al. (2013). “Modeling Channelized and Distributed Subglacial Drainage in Two Dimensions”. In: *Journal of Geophysical Research: Earth Surface* 118.4, pp. 2140–2158. DOI: 10.1002/jgrf.20146.