Review of “*Models for polythermal ice sheets and glaciers*” by Hewitt and Schoof

This paper is a simplified presentation of a mathematical model already described in *Journal of Fluid Dynamics* by the same authors [*Schoof and Hewitt*, 2016]. It clearly makes the model more accessible to the cryospheric science community, making easier the incorporation of this new approach in computational glaciology. The model itself is a very nice improvement of the mathematical representation of polythermal glaciers by improving the modeling of the water transport in the temperate ice. The strength of the model is also to stay simple enough to be easily implemented on current thermo-mechanical ice-flow models.

The approach uses the enthalpy formulation [*Aschwanden et al.*, 2012] that allows the use of an unique variable for both temperate and cold part of the ice. This avoids explicitly representing the CTS as a boundary condition and having two independent systems to solve in cold and temperate ice. Only the enthalpy gradient method has been used so far for glaciers. It assumes a diffusive water flux proportional to the enthalpy gradient which can lead to unrealistically high water content. The method requires therefore a drainage parametrization to cap the water content to an imposed value. In this study, the authors introduce a water transport according to Darcy Law and driven by gravity and water pressure gradient using the assumption of viscous compaction rate to compute pore pressure. The two main advantages are the water drainage is physically computed and the pressure gradient allows connecting water content in temperate ice to a subglacial hydrology model that would provide the adequate boundary condition at the bed.

The authors explore three different approaches through very pedagogic examples that clearly help to understand the difference between these approaches. They also conclude that just adding gravity driven water flow in the current enthalpy gradient method leads to very satisficing results compared to the full gravity and pressure gradient method (which need to solve a supplementary variable).

The paper is well written and structured. It is complementary to *Schoof and Hewitt* [2016] making easier the access of the model to the community. I think the manuscript deserves publication in The Cryosphere with few minor revisions.

General comments:

- Because mathematical and numerical aspect of the model have already been treated in *Schoof and Hewitt* [2016] and the aim of this paper is to communicate to glaciologist community, I think it would be better if this paper tries to link more the modeling results to observation of the "real" world. I know that very few observations of water flux through temperate ice have been done which gives lot of freedom to modeler… At least the authors should discuss in the introduction why water flow in temperate ice could be modeled as a porous flow by referring more to literature on this subject. Also it would be needed in the introduction to describe the difference between your approach and the existing ones. For exemple, *Fowler* [1984] also used a darcy law… I know this have been done more carefully in *Schoof and Hewitt* [2016] but I think it should appear also in this paper.

- The natural boundary condition at the base of a glacier for energy conservation equation is generally a heat flux coming from the ground. You should show an example using this type of boundary condition at least for the ice cap setting (probably instead of figure 8 which is not very useful).

- Why using $\nu = (k/\rho c)/100$ while *Aschwanden et al.* [2012] recommend $\nu = (k/\rho c)/10$ and most of people are using this regularization then. It would be better to compare enthalpy gradient method with a more "standard" ν parameter.

Specific comments

Section 2.3: I would present first the standard enthalpy gradient model, then the modified enthalpy gradient model and finally the compaction pressure model. It would avoid referring to section 2.3.2 and 2.3.3 in section 2.3.1.

Line 124: Discuss more about the value of k_0. Do you think large value of k_0 would be an adequate way to model water transport through macroscopic veins and crack? Actually, may be add this in section 5.2 and not here.

Line 174 -177: Any idea about $p_e'(\phi)$? May be develop a bit more about a model using $\nu(\phi)$ rather than constant ν.

Line 187-189: I guess it is because $\phi=0$ in the cold part?

Line 274: ~~finite~~ porosity : infinite porosity ?

Figure 3: In the legend, you say for large permeability $dPe/dz \approx (\rho_w-\rho)g$ from (14). I don't understand how you get this from (14).

Line 304-308: Could you explain more why pressure become hydrostatic in the model for large permeability. Also it is not clear to me why drainage is controlled by effective pressure in this case? Lot of the drainage still occurs via gravity… Do you mean porosity is controlled by effective pressure?

Line 351: ~~there~~

Line 410: Still not clear to me why effective pressure gradient balance gravitational term for large permeability?

Line 422: permeability: do you mean porosity here ?

Line 424: effective pressure gradient

Line 428: What do you mean by the margins of ice stream are another place where this may be relevant. Be more precise.

Line 451-457: Add a ref like [*Fountain and Walder*, 1998]

Reference:

Aschwanden, A., E. Bueler, C. Khroulev, and H. Blatter (2012), An enthalpy formulation for glaciers and ice sheets, *J. Glaciol.*, *58*(209), 441–457, doi:10.3189/2012JoG11J088.

Fountain, A. G., and J. S. Walder (1998), Water flow through temperate glaciers, *Rev. Geophys.*, *36*(3), 299–328, doi:10.1029/97RG03579.

Fowler, A. C. (1984), On the transport of moisture in polythermal glaciers, *Geophys. Astrophys. Fluid Dyn.*, *28*(2), 99–140, doi:10.1080/03091928408222846.

Schoof, C., and I. J. Hewitt (2016), A model for polythermal ice incorporating gravity-driven moisture transport, *J. Fluid Mech.*, *797*, 504–535, doi:10.1017/jfm.2016.251.