Second review of “A fast and simplified subglacial hydrological model for the Antarctic ice sheet and outlet glaciers”
By Kazmierczak et al.
Submitted to *The Cryosphere*

Overview

The authors of this manuscript have made substantial improvements addressing concerns and questions raised in the first round of reviews. They present a method for simulating subglacial hydrology on large scales (both in space and time) that captures several interesting qualities of potential drainage systems that may arise. The model assumes a steady state hydrological configuration and involves switches between different classifications of drainage types: efficient vs. inefficient, opening by sliding vs. opening by melt, close to the grounding line vs. far from the grounding line, hard bed vs. soft bed. While there are limitations, I think this is a creative approach with demonstrated practical use that has great potential for producing helpful advancements in understanding of the relationship between ice dynamics and subglacial hydrology on broad scales.

The revised manuscript is well organized and well written. I have a few relatively minor comments and questions, listed by line number below, along with a few typographical errors pointed out. With a bit of further refinement, this paper will make a nice contribution to the glaciological literature.

Specific Comments

Title: I like the new title, but suggest “Antarctic Ice Sheet” to follow convention (capitalized when referring to a specific named ice sheet)

Line 41: extra “a” before “small”

Line 42: Some mountain glaciers can surge remarkably fast, advancing significantly in sub-year time scales, and Antarctic ice shelves can break apart rapidly. I suggest adding a qualifier here: “... several orders of magnitude smaller than the typical response time of glaciers and ice sheets…”

Line 65: ice sheet–ice shelf model (replace “-” with “–” for clarity, otherwise this reads as sheet-ice)

Lines 91-92: This is a vague description of efficient criteria – perhaps a more quantitative statement would be better here. What qualifies as a large flux? Or you could describe physical characteristics of an efficient drainage system.

Line 122: This assumption may only be valid if there isn’t much water generated. If you have a substantial amount of subglacial water, this won’t necessarily be accurate.

Line 123: Does “sub-grid” here refer to your global or local grid scale?

Lines 149-150: Under what conditions was the dissipative melt negligible relative to the other melt terms? This can be an important source of basal meltwater depending on geometry etc., and in fact is the melt term usually responsible for triggering the channelization process. So, I don’t think the general dismissal of this term is justified by this statement – and you may be missing an important piece in the hydrology physics if you ignore heat from dissipation. This deserves more acknowledgement.

Lines 166-167: It seems inconsistent to assume fully turbulent flow with large fluxes as described here, but neglect heat from dissipation in Eq. (3). This limitation should at least be mentioned and justified.

Lines 219-220: Another interpretation of boundary conditions at the grounding line applies when it is actually grounded ice. Rather than N=0 as is appropriate for floating ice, in the grounded case the subglacial water pressure could be equal to the pressure of the overlying water where it is discharged. This may be a small difference, but should ideally be tested or at least mentioned here.

Lines 260-261: Melt from dissipation was indicated to be neglected above (text following Eq. 3), so how does large flux lead to higher melt in your model? This is not clear.

Line 262: Clarify that this is only because of the steady-state condition that ice creep must increase to counter increased melt with increased flux. In a dynamic system that is not at steady state, these opening and closing rates are not necessarily in balance.

Line 270: I suggest rewriting slightly to clarify that these are modifications that may be imposed to force the model to produce an entirely efficient or entirely inefficient system. As it is currently written, it can lead to confusion about what is included in the model. Suggested rephrasing: “By removing the opening term associated with the sliding over obstacles, // vb // hb, from equations (5b) and (6a), it is possible to force the model to produce an entirely efficient drainage system. In this case, we also set Qc = ∞, which guarantees that the conduit geometry is the one of an inefficient system for soft beds. Similarly, to force an entirely inefficient system, the efficient component, Qw // ∇ϕ // /ρiLw, can be removed from (5b), together with the condition that Qc = 0.”

Lines 281-282: Why use a different sliding law with the hydrology simulations (regularized Coulomb) than what was used for generating the reference state (Weertman)? I imagine you could justify this because the effective pressure varies spatially in the hydrology simulations, while in the reference state spin-up you likely assumed some spatially uniform fraction of overburden or something. Please explain.

Lines 301-303: Suggested rephrasing for enhanced clarity: “We also compare the impact of the drainage efficiency, by comparing the cases where only efficient (eff) or inefficient (ineff) systems are allowed to develop. Note that, by default, the switch between both systems (efficient/inefficient) is determined based on the subglacial water flux magnitude.”

Line 309: “correspond”, not “corresponds”

Line 518: “when basal cavities are growing” should be “*where* basal cavities are growing” (your model is considering steady-state configurations, so this should be a spatial description, not temporal)