Review of Shapero et al.

Doug Brinkerhoff

February 2021

Summary

In 'icepack: a new glacier flow modeling package in Python, version 1.0', Shapero and co-authors present a promising new ice sheet modeling framework. The framework contains mechanisms for solving both the prognostic mass balance equations for updating ice sheet geometry, as well as diagnostic solvers for approximations to the non-linear Stokes' equations. Throughout both the software and the manuscript describing it, the authors focus on ensuring usability (readability), a trait that is bound to make this software (and paper) frequently used. Despite its accessibility, the capabilities of icepack are already impressive, made all the more so by its explicit design prioritization of easy extensibility.

I find the manuscript to be exceptionally well-crafted, and I think that it could be published as is. That said, I offer a few suggestions, comments, and points of clarification below.

Minor points

L15-18 It would be nice to have a cited example or three for each of these suggested use cases. This would help the reader identify the kinds of practical problems where icepack might fill a need.

L74 A low aspect ratio isn't really an approximation; it's an existential fact. The approximation that the first order approximation makes is that vertical resistive stresses (or bridging stresses as they are referred to later in this manuscript) are small, pressure is hydrostatic, and bed slopes are small.

L92 It would be useful to offer a reference regarding an anisotropic fluidity.

L100 Not clear where the Legendre transform enters: the viscous and frictional dissipation can be read off from Eq. 4.

Eqs. 6 and 12 While I understand that it is convenient to manipulate the action to reflect the algebraic manipulations to yield the analytical SIA solution, the break in symmetry between Eq. 6 and Eq. 12 is frustrating, given that they both are name 'gravity', and that they should in some sense be the same regardless of which strain rates are assumed to be zero.

L144 That the terminal potential term, Eq. 13 disappears is not obvious. This should probably be clarified, since many readers will be surprised by this.

L152 Cite the method of manufactured solutions.

L159 The benefit to avoiding complicated 3D meshing should not be understated, in addition to the reduction in the cost of computational solution.

L188 This is a bit of a red herring, given that impenetrability is a natural boundary condition on the incompressibility equation. It can go right in the action principle, no extra Lagrange multiplier (besides pressure) needed.

L367 I'm surprised by this. For challenging geometries, I've always needed to stabilize even when using implicit Euler. Are you sure that implicit Euler is unconditionally stable even for non-linear advection like this?

L453 Many advances have occurred in the last 5 years regarding gradient descent due to its necessity for optimizing neural networks. These may yet be useful in this context if you have to deal with a large scale optimization problem where forming the Hessian becomes prohibitive.

L459 Gauss-Newton needs a reference if you're not going to describe it here.

Eq. 34 It's worth noting that the Schoof law is phenomenological, and was selected because it has the right shape and obeys Iken's bound. As such, if your sliding law obeys Iken's bound and looks right, then it's not any less valid.

L580 I think that having to specify a variational principle for the sliding law is useful because it guarantees a law that is positive (semi-)definite, as it must be to be physical.

L701–713 I enjoyed reading this paragraph, but I wonder if stabilizing the Stokes' equations is the best illustration of the point, given that icepack does not in fact have Stokes' equations implemented (although I imagine it could be done in short order). Maybe stabilizing a transport equation would be a more appropriate case?