Geosci. Model Dev. Discuss.,
https://doi.org/10.5194/gmd-2019-244-AC2, 2019

Geoscientific Model Development Discussions

Interactive comment on "A full Stokes subgrid model for simulation of grounding line migration in ice sheets using Elmer/ICE(v8.3)" *by* Gong Cheng et al.

Gong Cheng et al.

cheng.gong@it.uu.se

Received and published: 10 December 2019

article [english]babel amsmath amssymb color

Response to Anonymous Referee #2

December 10, 2019

This paper tries to implement the subgrid scheme of grounding line (GL) movements in Elmer/Ice and test it with the 2D MISMIP benchmark. The "full" Stokes model is computational intense, especially for solving marine ice sheet problems where very fine mesh resolution is usually needed around GL to accurately capture the movement of GL. Thus, a subgrid scheme study like this paper is certainly valuable. However, the current version of this manuscript is probably not ready yet for a consideration of publication, due to the following reasons:

1. The authors use a hydrostatic (first-order) approximation to determine whether a node is floating or grounded, which looks disappointing for a "full" Stokes model. In Elmer/Ice, to solve the contact problem of GL dynamics, the normal stress (nodal force) was actually used in previous studies (e.g., Durand et al., 2009). It's surprising that this paper doesn't use that, which, from my point of view, is not a Stokes solution.
   Response: The GL position is determined by linear interpolation in $\chi = \sigma_{nn} + p_w$ with σ_{nn} given by the full Stokes solution. A first order approximation of the GL position is analyzed in Sect 2.4 by perturbation theory in (Schoof, 2011) and computations in (Nowicki and Wingham 2008) show that χ is linear in x for $x <$

x_{GL}. The GL position in other papers solving the FS equations is located in the nodes of the mesh which is a zeroth order approximation. The basis functions in our FEM model are close to linear at the lower boundary and $b(x)$ is linear between the nodes. Hence, a linear approximation for the GL is natural.

2. For testing the capability of the subgrid scheme, the authors should at least do the MISMIP3d experiments, in order to see how the GL move in y. The MISMIP benchmark is good, but I don't understand why not trying the MISMIP3d since it's been out there for a couple of years. The authors have some discussions of extending the 2d implementation to 3d, but perhaps it's better to just test it.
Response: Implementing and testing the GL treatment in the present structure of Elmer/ICE would require a considerable effort of many months.

3. The writings, particularly the introduction section, still needs improvement.
Response: The Introduction has been shortened with fewer references to other work.

1 Technical Comments

- Citation style throughout the whole paper needs to be corrected
Response: The correction has been made.
- In the title, there should be a space right after Elmer/ICE, or just remove (v8.3)
Response: The correction has been made.
- Line 13: change it to "...an indicator of ice sheet advances or retreats"
Response: The correction has been made.
- Line 15: "on West Antarctica" to "in West Antarctica"
Response: The correction has been made.

- Line 18: In theory the Stokes model is the most accurate, but in reality it might not the one that shows the best match to observations. So please make an explicit and correct statement.
Response: We have added that the FS model is the most accurate in theory. If it is the most accurate one then the analytical solution to the equations should also have the best agreement in general with observations. This is our interpretation of an accurate model. Analytical solutions are not known and they are approximated by numerical solutions. If the FS model is not the best one in comparison with data then the numerical approximation is not sufficiently accurate in our opinion. Most other equations for ice simulation are simplifications of the FS equations where terms have been removed. If the terms are small then the solution to the simplified equations is close to the FS solution but if they are large then their solution may be closer to the observed data occasionally but in general that is not the case.
- Line 25: It is the longitudinal stress gradient, not longitudinal stress, that controls the flow of ice shelf.
Response: The correction has been made.
- Line 121: change "net surface accumulation/ablation" to "surface mass balance"
Response: The correction has been made.
- Line 124: change "net accumulation/ablation at the lower surface" to "basal mass balance"
Response: The correction has been made.
- Line 134: change "short interval" to "short distance interval"
Response: The correction has been made.
- Line 270-273: For case i, how come the GL position is at the floating part? It may look reasonable numerically, but it's totally not physical.

Response: Only a part of the element is floating with floating boundary conditions. The angle between the element and the bedrock is small in practice and exaggerated in the figure.