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The Cryosphere
Discussions

Interactive comment on "Parameterization for subgrid-scale motion of ice-shelf calving-fronts" *by* T. Albrecht et al.

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This paper presents the numerical handling of an advancing ice shelf front, and is presented as a companion to several other papers dealing with modifications that the authors have made to the model PISM. This paper does not deal with a specific calving parameterization, which can be seen as the "physical" side of the calving problem, but rather how to deal with the "technical" side: given a calving parameterization, there is a velocity associated with the ice shelf front (either positive or negative), and if the ice momentum and mass equations are solved on a rectangular grid, then they must account for this velocity and must reproduce analytical solutions wherever available. What I like about this paper is that the authors bring attention to this "technical" side of calving; in the literature on calving studies I have seen not much mention is made

of it, and yet dealing with it is a prerequisite in studying and investigating calving parameterizations. For example, the problem of an "overly diffusive" front is one that I am not sure all ice shelf modelers are aware of, but certainly should be. The fact that they chose a very simple parameterization to work with might not be a problem.

That being said, there are some issues on which the manuscript is unclear and/or confusing. The treatment is described in great detail for the 1D (flowline) model, but the 2D treatment is given almost as an afterthought. This is unfortunate, since the 2D treatment is, or should be, the main contribution of this manuscript. Developing the 1D parameterization oneself would not be that difficult (and, by itself, not worth writing a paper about). Detailed comments follow, and typographical/grammatical errors are at the end.

Section 1 Comments

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paragraph beginning page 1498, line 18: in presenting this issue, you have already assumed a numerical discretization, no matter how common. I have no idea how a 10th-order polynomial finite-element solution would behave in such a situation. You should present it as an issue with the chosen discretization.

Section 2 Comments

Eqn 3: This looks like a CFL condition that would apply to a 1D model. Is the same applied to the 2D version of the advection equation? Or is there a numerical factor?

Section 3 Comments

Overall: There is subscripting in this section to denote which grid cells are being discussed. But there is no mention of *when* things are updated, initialized, etc. What is the order of operations in your algorithm? e.g. do you calculate R for partially-filled cells at the end of a timestep, once thicknesses are updated (and therefore using the new value of H_c to find H_r)? My guess would be that over a given timestep, you (0) have the old value of thickness, R, and H_r (Hˆn, Rˆn, H_rˆn), and you first (1) calculate velocities (uˆn), then (2) advect thickness to get Hˆ{n+1}, (3) determine which cells are now partially filled based on H_rˆn, and finally (4) calculate Rˆ{n+1} for the partially-filled cells, using new values of H_r determined from Hˆ{n+1}. (superscripts denote time level.) This seems to be the most direct order of operations, but then again it may be problematic (see below). And anyway I should not have to guess.

p1504, line 22: where do the values of V_{i+1} come from? That is, you clearly have a velocity at each filled/partially-filled interface which is negative and larger than the ice velocity - but which thickness is used to find volume flux? H_r? This should be mentioned as it is part of the parameterization.

p1504, paragraph beginning line 26: This is an instance where insufficient detail is given on the 2D treatment. The issues I can think of: (1) Is it not possible that this could result in H_r being thicker than one of the adjacent cells? Is this not an issue when the cell becomes filled and is now thicker than an upstream cell? (2) With the CFL condition as in eqn (3), this could result in, say, an empty cell (R=0) becoming overfilled in a single step, could it not? And a similar issue for retreat, if a full cell is drained by more than one partial cell? (3) For retreat: does each interface have an associated volume flux, as in p1504,line 22? If a partial cell is completely drained, how is the excess (negative) volume partitioned to multiple adjacent full cells? (4) If there are 3 adjacent cells, H_c is averaged over all 3 to get H_r?

Eqn(8): I have several comments/questions about this H_{r,red} formulation - (1) If a cell is filled over the course of a timestep, is its thickness then set equal to H_r (or H_{r,red}, whichever is being used)? Is this thickness then the H_c that is used to find H_r, and R, for the new partially-filled cell? If not, please explain the process in more detail. But if so, I can see a way that a completely ice-free cell can become

completely filled (with excess mass that needs to go into an additional cell). CFL would not allow the cell to become completely filled with H_r = H_c, but if H_r is then adjusted according to eqn (8), R could increase and potentially become larger than 1. Perhaps this is not possible, but a better explanation of the algorithm (re: my comment about order of operations) would make this clear. (2) It is not clear how this would work in 2D, since each neighboring cell would give a different H_{r,red}. (3) In a polythermal version, would you adjust the parameter C?

Section 4 Comments

In this section, I have no problem with the material up to eq. 12. However, I find parts of the descriptions of the experiments unclear. I find it easier to organize my comments by experiment, not by page/line number. I hope that is alright.

The Experiment corresponding to Fig. 4:

You say (p1507, line8): "Its [the ice-shelf extension scheme used in PISM] effect on the ice-shelf propagation is shown in comparison to a model result with applied CFBC in the flowline case (Fig. 4)." And so I expect that the "no CFBC" case in Fig 4 implements the shelf extension scheme described in the introduction. But p1507, line 11 says that the shelf extension scheme is not used. So is the shelf extension scheme applied in any of the experiments? And if not, what is used in the case where the CFBC is not used? The ice shelf needs a condition at each boundary. The upstream boundary condition is one of velocity; if the CFBC is implemented then there is a stress condition at the front. If I understand the shelf extension correctly, the stress condition is applied at the boundary of the computational domain (not the ice shelf). But it is still applied somewhere. If you don’t use the CFBC or shelf extension scheme, what is the seaward boundary condition of the equation solved for velocity? (Also, I don’t understand the sentence beginning p1507, line 18: as written it does not make sense.)

The Experiment corresponding to Fig. 5: p1508 l2: either do not say "(higher order terms in approximation)" or explain what you mean.

The Experiment corresponding to Fig. 6:

For the most part I thought this was clear, and the results shown for variant 2 are interesting. My question, again, is about "variant zero": what is the boundary condition on the velocity solve if neither CFBC or shelf extension are used?

2D Experiments:

As I mentioned before, these are more interesting and not much text is devoted to explaining them. Are these steady states? Are you again using the 250-m calving rule? Which "variant" are you using? How is the boundary condition at the grounding line decided upon? How far is this configuration from an initial condition? Can they not be compared against the actual ice shelf fronts? (when the ice shelves existed, of course...)

Typos and grammatical errors:

p1499 l4: drives l10: does not agree

p1502 l15: generalize

p1503 l13: remove "also" l14: replace "was" with "is"

p1507 l12: "shows" l12: m/a

p1508 l2: three-step l10: you already said this. l20: not "stated". "seen" maybe?

p1509 l8: extension

Interactive comment on The Cryosphere Discuss., 4, 1497, 2010.