The Cryosphere Discuss., 6, C2218–C2220, 2012
www.the-cryosphere-discuss.net/6/C2218/2012/

The Cryosphere
Discussions

Interactive comment on "Ice-shelf buttressing and the stability of marine ice sheets" *by* G. H. Gudmundsson

Anonymous Referee #2

Received and published: 19 November 2012

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Interactive Comment

Review of Ice-shelf buttressing and the stability of marine ice sheets (G H Gudmundsson)

19 November 2012

This paper is essentially a companion paper to the paper "The stability of grounding lines on retrograde slopes" (also on TCD, and to which I will refer to as GH12), as it represents a more in-depth analysis of an aspect of the experiments in that study, namely the stress balance. Ice shelf buttressing is oft-talked about but rarely examined quantitatively, which is what is done here for the experiments in GH12. There is a somewhat lengthy discussion of the notion of buttressing and the balance of stresses at the grounding line, but I think this might be good for someone not as familiar with the literature. Some metrics used to examine buttressing are defined, and discussed in the context of previous experiments, and various parameterizations for grounding line flux.

I think this is a strong piece of work and deserves consideration, but not until some issues are addressed. I have some comments on the manuscript, and also I disagree with one of its main conclusions (below).

1. I looked both in this manuscript and in GH12, and I could not find the answer: aside from the calving front stress condition, what were the lateral boundary conditions on the "Ua" model? From GH12, Fig 2, it looks as though there might be no-slip sidewalls up to x=1500 km, and stress-free sidewalls downstream of that, but I am not sure.

2. It is stated on page 3940, and I think elsewhere as well, that "unconfined ice shelves do not cause any buttressing". This is not strictly true, and I am not talking about higher-order models. What is true is that the *contour integral* along the grounding line

$$\int_\Gamma h\sigma_h \cdot \vec{n} ds \tag{1}$$

is equal to

$$\int_\Gamma \frac{1}{2}(1-\frac{\rho}{\rho_w})\rho g h^2 \vec{n} ds, \tag{2}$$

where Γ is the grounding line. This does not imply pointwise equality of the integrands, which would be needed to make the statement in question. And in fact, it is possible to produce solutions to the SSA balance for an unconfined shelf where the shelf has an effect on grounded velocities - see the example at the end of Schoof (2006, JFM).

3. Top of page 3945: You should also mention the First-order stress balance. The stress boundary condition will be different with or without a shelf even in 1HD with no buttressing: the vertical integral of the backstress will be the same whether there is a shelf or not, but its variation with depth will change, and this will have nonzero effect on the stress balance within the sheet. I am not sure how far this effect will penetrate into the sheet, but certainly as far as a bending moment.

4. Eqn (17). You mention that there are implicit assumptions in this expression but do not say what they are. Nor are they given anywhere else in the literature, as far as I

know, including the Schoof 2007 paper, and so they should be addressed somewhere in this paper. For this expression to hold, tangential "buttressing" stress (your T) must be vanishingly small compared to N and the radius of curvature of the grounding line must be large compared to the "grounding zone". (And even then, I don't think there is a mathematical argument given in the literature for why this should be so, though I am not suggesting you give one here.) I point this out not just for the sake of veracity of the discussion, but because these conditions fall down along certain parts of the grounding line in your experiment...

5. page 3946, line 10: you do not mean that it should depend locally on thickness?

6. page 3951, lines 21-22: "a number of models"? i think you mean a number of experiments with the same model?

7. page 3953, line 5: This sentence is a tautalogy! *where* can agreement be expected?

8. There is no real discussion of *why* expression (17) is accurate in certain places and not in others (see (4) above).

9. And finally: one of the main conclusions is that expression (17) is sufficiently accurate to use in contintental models, etc, and I think the argument is that where GL velocities are high, then (17) is a good fit. I cannot prove or refute this statement, but to take on faith that it will lead to reliable results, given that the conditions where we would expect it to be accurate are difficult to assess a priori, seems a bit risky to me. But also, the conclusion is based on the assumption that flux across the GL does not matter in those regions where agreement is poor, e.g. the margin. I don't think this is true. Even though velocities normal to the GL are much smaller than those transverse to it, situations could arise where the mass flux normal to the GL is an important factor in evolution of ice shelf thickness close to the margin. And the thickness of the ice shelf near the margin will strongly effect its ability to transfer stress, i.e. its buttressing capabilities.

Some minor typos I saw:

p3944, line 14: "shelves" not "shelf"

p3946, line 16: precise

p3948, line 19: "were", not "where" (also p3950, line 13)

p3951, line 22: "case", not "cases"

p3953, line 2: I understand this sentence, but it is *really* awkward

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