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The Cryosphere Discussions

Interactive comment on "A three-dimensional full Stokes model of the grounding line dynamics: effect of a pinning point beneath the ice shelf" *by* L. Favier et al.

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Interactive Discussion

Discussion Paper

Response to reviewer R. Gladstone

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This paper presents a 3D full Stokes model utilising a refined (but not adaptive) mesh. The model is described and is also tested for an idealised setup involving a bedrock hump beneath an ice shelf.

The development of this model is significant. The results presented here are not particularly surprising or ground breaking, but are a useful inclusion in that they demonstrate plausible, and more importantly reversible (which is often problematic for ice sheet models), grounding line migration, and they investigate processes relating to pinning point mechanics in greater detail than previous studies.

I would like to see this paper published. Given that the main significance of this paper is the model itself, the journal "Geoscientific Model Development" might be more appropriate than "The Cryosphere", but I have no objection to this paper being published in “The Cryosphere” if the authors and editor see fit.

I have no major criticisms of this paper, though the text does need to be improved in a number of ways. The figures are in general excellent.

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In particular more information on the spin up to the initial steady state for the experiment involving the ice rise and sea level changes is absolutely essential in order to properly demonstrate reversibility (see specific comments for details).

The language is in places excessively verbose, not terribly clear, and contains quite a lot of repetition. The text of the whole paper could benefit from a thorough read through and tidy up. It needs to be clear and concise. It contains quite a lot of repetition. I have included a few suggested modifications as examples in my specific comments section. Oh, and it contains quite a lot of repetition.

The main modifications that have been done to the paper are the following:
- We rearranged the paper in order to clarify it. A 3rd section dedicated to numerics has been added, with details about the mesh choices, the 3D geometry spin up procedure and the model algorithm. All the numerical experiments have been gathered in a 4th section (verification experiment, pinning point experiment and mechanical reversibility experiment). The results have been discussed in the corresponding subsection, and the conclusion has been rewritten to be more concise and straightforward.
- The verification experiment has been redone with a larger migration of the grounding line (it is related to the sensitivity study asked by the other reviewer, more explanations in the response to him).
- The non relevant repetitions have been removed.
- Figure 4 and 6 have been removed.

I look forward to seeing the model applied to real world situations.

Specific comments

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Page 1997

Line 12 remove “approximative”

Done

Line 14 ...is a potential source of...

Done

Lines 17-19 I am not convinced this statement is true. Please back it up or remove it. I think the mass balance is controlled by net accumulation at the surface vs ice shelf melt and calving.

You are right, we wanted to talk about the dynamics of the ice sheet, we modified the sentence.

Line 28 I don’t think you mean “lack of understanding” here, it is not understanding of the physical process that causes problems for grounding line modelling but rather the scheme itself. How about “lack of predictive ability” instead?

As we totally agree, we followed the recommendation of the reviewer.

Line 29 “degree of complexity resolved by the numerical models” – what do you mean?

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If you are referring to how many components of the stress tensor are removed you can be more specific about this. By “grid” you mean resolution?

The sentence was too vague, it has been reformulated.

Page 1998

Line 3 “not really” is rather vague – have grounding line studies been done with this kind of model or not? Perhaps you need again to be more explicit and say that while 2D full Stokes grounding line migration studies have been carried out, this is the first 3D study.

You are right, we rephrased the sentence.

Line 7 onwards. I am a bit confused by what you call “moving”. The distinction between an adaptive mesh and a moving mesh is an important one, and both methods have been employed successfully (see e.g. publications by Vieli or Gladstone and of course Durand). The resolution requirement when using a moving mesh with grid points that track the grounding line is not as strict as when using adaptive refinement in which high resolution tracks the grounding line but not individual grid points. Careful about saying that a “highly refined grid” is required. The grid could simply be high resolution everywhere (e.g. Gladstone 2010 Cryosphere paper).

We removed the sentences mentioning the moving or adaptive mesh techniques. We don’t talk about it anymore.

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I suggest keeping separate the description of mesh requirements and simplifications to the stress tensor.

We followed this suggestion.

Page 1999

Lines 6-7 repetition, you've already said what full Stokes means.

We deleted the repetition.

Lines 6-21 There is far more detail here than is needed, especially since some of this detail is repeated later on.

We removed the non relevant repetitions.

Page 2000

Line 9 "8-node" not "8-nodes"

Corrected

Line 10 repetition, you've defined the grounding line in the previous paragraph.

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We removed the repetition.

Page 2001

Line ? "ice is assumed to be isothermal" – emphasize that this pertains to the experiments in the current study, this assumption does not have to be a part of a full Stokes model.

The sentence has been moved to the verification section.

": : :consisting in the momentum: : :" should read ": : :consisting of the momentum: : :"

Corrected

Page 2002

Lines 15-16 reference section 2.3.5 re lateral boundaries since this has not yet been mentioned.

Reference to section 2.3.5 added.

Page 2004

Lines 5-8 grounding line migration is just one of several processes mentioned in the AR4 that models do not well represent. It is the most important one for Antarctic

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marine ice sheets.

You are right, the sentence has been rephrased and now explains this.

Line 10 I have seen several papers report “neutral equilibrium” in ice sheet models but never seen any evidence that such a thing occurs in models. Note that the existence of a region containing multiple equilibrium grounding line positions is not in itself sufficient to say that neutral equilibrium occurs. See also description in Gladstone 2010 JGR paper which describes this phenomenon without using the term neutral equilibrium. Perhaps better to say “multiple steady state grounding line positions”. I can give more explanation of why this is not n.e. if you like, let me know.

The word “neutral equilibrium” was misemployed. We rephrased the sentence without using this term.

Lines 19-23 this seems more like a description of model spin up than a description of how you come up with the mesh. The method for forming the mesh appears to be described only in a vague hand waving way.

As mentioned above, descriptions of model and numerics have been moved in different sections.

Section 2.4 as a whole should probably form a part of the experiment description section as it pertains more to the set up for the particular experiments presented here than to the model itself in a general sense.

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As mentioned above, we followed these recommendations.

Page 2006

Lines 7-11 there is no need to explain the values used in the mask, the readers do not need to know this. All they need to know is that the grounding line is defined as a grounded node with at least one floating neighbour.

You are totally right. We removed these technical details and also Figure 4.

Section 3. Is this validation? It seems like verification to me. Verification is the process of ascertaining whether the model correctly solves the intended equations and provides convergent behaviour. Validation is the process of ascertaining how good a job the model does of representing the real system. I think this section should be called verification not validation.See for example, http://jtac.uchicago.edu/conferences/05/resources/VV_macal_pres.pdf

Thanks for the link, it was helpful. Following the recommendations from both reviewers, the word “validation” has been replaced by the word “verification”

Page 2007

Line 3 describe the spin up properly here, or reference section 2.4 at least. And YOU MUST mention the initial thickness of the slab used from which the 2D steady state was spun up. Please also say whether any significant adjustment from the 2D state occurred during the final century of 3D spin up.

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We added a reference to the new spin up section.

Page 2008

Line 13 remove “initial”

Done

Page 2009

Line 3-4 this is a very vague statement and should probably be clarified or omitted. You achieved a maximum resolution of 50m. You have not demonstrated convergence of grounding line behaviour with resolution but previous studies with this type of model (Durand papers) indicate that 50m is pretty close to convergent behaviour.

We omitted the sentence.

Line 8 is there a naming convention to your experiment? Does “pp” stand for something significant? If not then calling it experiment 1 or experiment A might be less confusing to the reader?

We renamed both experiments with letters A and B instead of pp and back, respectively.

Line 14 “mechanical irreversibility”? Surely any irreversibility is a numerical artefact

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and has nothing to do with the mechanics?

In that case, the irreversibility is due to mechanics. The sentence has been reformulated though.

Page 2012

There is a LOT of repetition in the conclusions. You do not need to provide a detailed description of the experiments in the conclusions. Most of the conclusions section is a repeat of sections 3 and 4 and needs a complete re-write. Ask yourself, what are the important points you want to get across? For example in section 3 you demonstrated that numerical irreversibility with a grounding line resolution of 50m is around 1.5km in this experiment. If you compare that to traditional fixed grid models which exhibit irreversibility of tens or even hundreds of km (e.g. Gladstone 2010 JGR) you might conclude that this is a successful verification. So don't just repeat what you've said in the results section. Say why it is relevant. I think your conclusions section should be much shorter, with the main conclusion being that you have perhaps the best tool in the world for grounding line modelling (if only you can afford the cpu time to run it!).

Thanks for the last part of the comment.
As already mentioned, the conclusion has been shortened.

Page 2014

Lines 15-21 these lines are a vague discussion about resolution. You haven't done any experiments that shed light on convergence with resolution, though you have shown

you are sufficiently aware of the problem to design a plausible reversibility experiment. I would say that you have no conclusions to offer about the resolution issue, beyond the point made above that your model performs well at an achievable resolution (50m near the grounding line). I think you should remove this paragraph from the conclusions. It is pretty much a repeat of what you have said in earlier sections and isn't really a conclusion anyway.

Removed.

Lines 22-29 these lines are fine! Keep these lines and re-write the rest of the conclusions and don't be afraid to have a short and snappy conclusions section!

Figure 1 "n" is pointing straight up, shouldn't it be normal to the ice surface?

The figure has been redrawn.

Figure 4 if you follow my suggestion in the text to remove the mask values -1, 0, 1 then you should remove them also from this diagram.

Removed.

Figure 5 if you want to cater to people who like looking at pictures but don't like reading the whole text you may wish to emphasize in the caption that the 60km width shown does not represent the full domain (which is symmetric)

Done.

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Figure 6 you might wish to emphasize that you have zoomed in on the x axis: the zero near the origin refers only to the y axis. The colour scheme is a little hard to make out, but then coming up with 48 different colours is rather challenging!

Following the recommendation of the other reviewer, we removed this figure.

Figure 8 the text that says “450” appears to be at about 430. Not 450 anyway!

As mentioned above, the verification experiment has been redone. Thus, this figure and the previous one have also been redone.

Figure 10 grounded/floating the wrong way round in legend at top left? Can you increase the line width on the coloured contours? The colours are a little hard to see.

Corrected.

Figure 11 should any of these have multiple grounding lines? In which case you are showing only the most landward gl? Maybe use dashed lines for y=50km?

The figure has been clarified.

Figure 12 caption mentions dashed line but all lines are solid

Right, the word dashed has been removed.

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