The Cryosphere Discuss.,
doi:10.5194/tc-2017-53-RC1, 2017

The Cryosphere Discussions
Open Access
EGU

Interactive comment on "Ice shelf fracture parameterization in an ice sheet model" *by* Sainan Sun et al.

Anonymous Referee #1

Received and published: 3 May 2017

The authors have implemented a new representation of continuum damage mechanics into the ice dynamics model BISICLES, providing a way to study feedbacks between flow dynamics and damage-induced softening of the ice. To compare results from their modified model to standard results in the absence of damage, they follow the design of the MISMIP+ experiment. We believe that a number of points need to be addresses before publication. We also suggest additional experiments and an expansion of the discussions section, which could strengthen the manuscript.

In keeping with previously published papers, the authors adopt an advection scheme for damage. However, to the best of our knowledge, the authors suggest a new way to treat the source of damage in the advection equation, as detailed in section 2.2. The source is proportional to the local crevasse depth (surface + basal), where crevasse depths are calculated from a zero-stress criterion following (Nye 1957). We encourage

Printer-friendly version

Discussion paper

the authors to expand on the differences/parallels with existing research on continuum damage mechanics, to put their work into context, and to better motivate this approach. How and why is it “better” than previous work such as [Krug et al. 2014, Borstad et al. 2012, Pralong and Funk 2005]? For example, contrary to these studies, the authors do not implement a stress threshold for the formation of damage, and assume that non-zero damage is present in any tensile stress environment. Is this realistic, and how does it affect the results? Presumable the qualitative nature of the results remains the same, but it might become important at a later stage, when e.g. calving criteria are considered?

With regards to the results, the text provides an adequate description and explanation of the findings, although we would like to add a few comments/suggestions:

* The authors should specify how d_w (crevasse water depth) in Eq. 8 is determined. Is it set to a constant value, and how is this value chosen?

* In Figure 8, a compelling argument is made that evolving damage could play an important role in simulating grounding line retreat/advance. However, the results are only discussed very briefly, which is disappointing. To strengthen their point, could the authors perform inversions for a spatially varying rate factor, using the surface velocity and geometry at different timesteps in the IceD0 and IceD1 experiments? It would be interesting to see how the rate factor changes over time, as one incorporates the effects of damage into its value. This could inform present-day model initialisation methods, as most models treat damage in the form of a spatially varying rate factor, which is kept constant in time.

* In order to increase the impact of this work, we suggest highlighting how the results have altered our understanding of damage, and indeed, whether it should be treated as a vital part of future ice flow modeling studies. Perhaps the authors could discuss in more detail the future directions of research (incl. possible calving laws?) they like to pursue, and whether this model can become a prognostic tool for calving?

* Finally, we encourage native speakers on the author list to check the spelling and grammar of the manuscript.

Below is a list of more specific comments and questions about the text. (P refers to page number; L refers to line number on each page)

P2L5: “extremely sensitive to calving”: I believe this statement could be misinterpreted as “more likely to calve”. Therefore, please change the wording to “ice shelves in the Amundsen and Bellingshausen seas are thought to be more vulnerable in the event calving. . .” or similar.

P2L15: what do you mean by “magnify”? Do you mean that propagation and penetration of fractures causes calving?

P5L25: point out that A’ is a constant, and not a spatially varying field

P6L1-3: The second question needs a better explanation. Perhaps write something along the lines of “If we adjust the rate factor such that the damaged model reaches a similar grounding line steady state compared to the undamaged model, how does the transient response between both setups differ, when subjected to an external forcing that leads to thinning of the ice shelf?

P6L12: reformulate this sentence as follows: “In order to start the MISMIP+ experiments from the required grounding line location at x=450m, we run a series of IceD simulations with different values of the rate factor A. For each value of A, a new steady state grounding line location is obtained, and we select the value A’ for which the location is closest to the originally required grounding line at x=450m. We will refer to this steady state as IceD0.”

P6L24: The reference to this table comes too late. Preferably refer the reader to this table before you start listing all the experiments, i.e. before line 5 on page 6.

P7L3: from hereon, the authors use capital letter D to refer to damage. Should this not be small letter d, in line with the definition in Eq. 10 as the vertical integral of the

damage?

P7L12: It is worth pointing out that a decrease in A leads to stiffer ice, making it intuitively easier to understand why this is the right thing to do.

P7L14: Reiterate that Figure 2 is for A' instead of A, and therefore the damage pattern looks different from Figure 1.

P7L14: Can you explain why the areas of high damage at the margins are not so well confined to narrow bands as in Figure 1?

P7L18: From the small figure it is unclear that the damage starts to grow a few kilometers upstream of the GL. Perhaps provide a zoomed-in version as an inset in Figure 2?

Figures 1-5: There is a lot of white space in all these figures that could be used to better display the details of your results. You should also consider choosing a different color to make the grounding line stand out better.

And a list of typos/suggestions where the text can be imporved. . .

P1L22: "former" -> replace by "previously"?

P1L24: ". . .Antarctica IN recent. . ."

P2L2: ". . .under THE present climate..."

P2L5: ". . .even A small amount. . ."

P2L6: "will trigger" is too strong, replace by "can trigger"

P2L13: "statistically continuum": what does this mean?

P2L17: ". . .based on THE calculation. . ."

P2L18: ". . .and THE calving rate. . ."

P2L22: reformulate sentence as follows: ". . .fields, and hence do not take into account

the stress history in the development. . .”

P2L24: “damage has AN effect on THE viscous behaviour. . .”

P2L29: “glacier’S”

P3L1: “state of art” -> replace by “state-of-the-art”

P3L6: “. . .the evolution of THE ice sheet, such as the speed and behavior of THE grounding line. . .”

P3L15: “. . .well in ice shelves. . .” -> “. . .well FOR ice shelves. . .”

P3L16: “. . .so given A bed elevation b and ice thickness h, THE surface elevation. . .”

P3L20: “. . .and THE two dimensional. . .”

P3L21-22: reformulate as “. . .is THE basal melt rate of the ice shelf. In equation (3), tr is the trace operator, E is the horizontal strain rate tensor. . .”

P4L2: remove “inland” as it is the same as “upstream”

P4L12: “proved” replace by “proven”

P5L12: “. . .represent THE effect of . . .”

P5L22: replace “sited” by “positioned”

P5L22: remove “towards the ocean”

P6L15: remove “. . .see the models respond...”

P6L24: remove “in real world”

P8L2: “extruds”??

P8L19: “floating” -> replace by “become afloat”

P8L19: “. . .and THE grounded area. . .”

P9L4: rewrite as “. . .The experiments Ice0 and IceD, which explicitly show the result of adding damage to the ice shelf, produced . . .”

P9L21: “as” -> replace by “at”

P9L25: rewrite as “. . .This does not mean that calving is unimportant for THE grounding line. . .”

P9L27: rewrite as “. . .the general case in reality, in particular for large ice shelves.”

P10L4-5: remove excessive use of commas

P10L15: “In Biscles_D, THE viscosity. . .”

P10L16: “. . .we see THAT the retreat of THE grounding line. . .”

Interactive comment on The Cryosphere Discuss., doi:10.5194/tc-2017-53, 2017.