The Cryosphere Discuss.,
https://doi.org/10.5194/tc-2017-180-RC2, 2018

The Cryosphere Discussions

Interactive comment on "Simulating the roles of crevasse routing of surface water and basal friction on the surge evolution of Basin 3, Austfonna ice-cap" *by* Yongmei Gong et al.

Anonymous Referee #2

Received and published: 12 January 2018

This study utilizes remote sensing data and two numerical models to study the initiation of a surge in Basin 3, Austfonna, Svalbard. The viscous ice dynamics model Elmer/Ice is used to produce maps of the basal friction coefficient for the basin, using satellite-derived surface velocity maps over the period 2012-2014. The model states produced by these inversions are used to initialize a discrete element model for simulating the locations and patterns of crevasses in the ice. The modeled crevasse patterns are compared with observationally-derived crevasse patterns. The locations of crevasses are used to infer the sources where surface meltwater can reach the bed. Hydraulic potential maps are created to infer the potential flow pathways of this meltwater along the bed. The modeling results support the hypothesis that the surge initiation was

the result of hydro-thermodynamic feedbacks associated with summer melt, in which meltwater reaches the bed through crevasses, which then lubricates the glacier and enhances longitudinal stresses, which then promotes the formation of new crevasses which increases the catchment area for subsequent surface meltwater.

This is a timely contribution to an important topic in glaciology. Crevasses are certainly important to many feedbacks in glacier dynamics, and this study combines a model that can explicitly create crevasses with a more traditional ice dynamics model that can simulate the time-evolution of the system. The manuscript is generally well written, although it could benefit from some minor polishing for English grammar and sentence structure. The model descriptions are somewhat incomplete, such that it would not be possible to reproduce or confirm the results of this study. This can be easily addressed with additional text describing some of the explicit modelling choices.

Specific comments:

L 27: "containing a marine-terminating..."

L 70: awkward sentence, perhaps "previous crevasse modeling studies..."

L 75, 198: discrete element models are not "first principle" models unless you are explicitly modeling a particulate medium. Glaciers are not composed of idealized spheres of ice connected in a lattice framework. These are model choices used to represent a certain class of phenomena, but such a model type does not arise inherently from first principles. This is not a criticism of the model itself, but it is misleading to consider it a first-principles model.

L 87: "surge that occurred"

L 92-94: You have here a $\sim$30 year discrepancy in time between the surface elevation model and the thickness observations used to create your bedrock map. Why not use the Moholdt and Kaab DEM that you later mention on L 110?

L 99-100: not a complete sentence

Section 2.3: this seems like it belongs more in the Methods section below, as it is not really “observations”

L 166: you mention modeling ice flowing over a rigid bed, but earlier mentioned that surge behaviour may result from ice flowing over a deformable bed. Perhaps worth commenting on this here?

L 175: You mention the “slippery” terminus, but wasn’t the terminus the last to mobilize when the surge initiated? Maybe I’m missing something here, or perhaps you’re describing the terminus during the surge?

Inversion routine: did you add any regularization in your inversions to prevent overfitting the observations? If so, how did you decide how much? If not, why? This seems to be an important point. Regularization is commonly (and appropriately) applied in this kind of work. If you used it, you need to describe it in detail here. If not, some justification of why not is needed.

L 192-193: Ice temperatures are quite important in this kind of modeling. More description is needed here on how you computed spatially-varying temperature fields. Even if the details are in another reference, a general description of how you went about this is needed.

L 202: Elastic deformation is often considered static, that is there is no time dependence. HiDEM is not a static model, but rather a dynamic model if you are using time stepping and accounting for dynamic stress propagation. Perhaps a semantic point...

L 203: typically a modeled glacier will approach a new equilibrium. . . (real glaciers do not produce crevasse fields in minutes!)

L 204: See my comment above about reproducibility. A lot of choices are made when setting up a numerical model. For a study to be able to be reproduced/verified, you need to describe these choices. It’s okay to refer some general description in a reference, but there is essentially no detail on the HiDEM model implementation here.

What kind of fracture criterion was used? How was the time stepping implemented? What kind of stopping criterion was used for the time stepping? How large are your discrete particles? Are they uniform in size and spacing? How sensitive are the model results to these choices? Would modifying any of these choices lead to better/worse agreement with the crevasse observations from this study?

Basal friction maps: some metric of the misfit (e.g. root mean square) would be useful to report to give an indication of the quality of the inversions. The misfit panels in Figure 3 have quite a lot of saturated regions on both the high and low ends of the misfit color scale. With these alone it is difficult to judge the quality of the fits.

It would be nice to see the evolution of velocities along with the friction evolution, for context.

L 232-233: I’m not sure what you mean by “keep” the fractures

L 235-235: the additional black region you mention is difficult to see in the figure. I’m not sure I see what you mean.

L 244: by "appropriate" you really mean you re-sampled until you got the best agreement. This is not necessarily an objective "appropriate" resolution for comparing model output with observations (smoothing crevasses over 4.5 km kind of defeats the purpose of having discrete crevasses, doesn’t it?)

L 261: 60 degrees is quite a mismatch, any comment on why this is the case here? Panel 6c is mentioned in the caption of Figure 6, but not shown

L 314: “factures” → “fractures”

L 319: “emphasis” → “emphasize”

L 319-320: awkward sentence

Figure 4: some dates are cut off in the panels

References: check the reference list against those used in the text, it appears that a separate reference list has been concatenated to the end of the document (different font)

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