

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 #1

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General comments:

This is an interesting study that employs several modeling approaches and a variety of remotely-sensed data sets to explore the role of water delivery through crevasses in the surge of “Basin 3” within Austfonna ice cap in Svalbard. This peculiar surge, preceded by a multi-year seasonally variable acceleration, has been studied in some detail, but the precise interplay between basal friction, crevasse formation and water delivery to the bed not thoroughly explored. The authors use the 3-D Stokes model of ice flow Elmer/Ice to invert for the basal friction field using a built-in control method, and then use this field as input to HiDEM, a discrete element model, to predict the locations

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of crevasses before and after the surge. The calculated subglacial hydraulic potential distribution is used to determine the subglacial water routing, and to speculate on the mechanisms that relate surface melt to fast flow.

The scientific approach seems reasonable and the conclusions fairly well supported, though I would recommend the authors clarify some of their arguments before this paper is accepted (see below). Throughout the paper until near the end of the discussion, it was unclear to me whether the water routing to the bed through crevasses was a cause or consequence of the fast flow. The text seems to emphasize the role of water in facilitating fast flow, but the access of water to the bed via crevasses must be (at least partially) a consequence of the flow regime. I think I probably agree with the authors if they are arguing that the crevasses play an amplifying role, in that some reduction in basal traction is required to explain the formation of the crevasses that initially allow water to reach the bed. This water then accumulates in part of the domain and amplifies the acceleration of the outlet glacier. Though probably reported elsewhere, I found myself wanting to know if the thermodynamics work out: is there enough meltwater for this to be plausible given Austfonna’s thermal structure? The paper would be strengthened by a clear articulation of cause versus consequence.

Specific comments (page.line):

5.157-161: I read this several times and still have difficulty understanding how this procedure provides the validation data set.

5-6: For a technical journal like The Cryosphere, I was surprised not to see the model governing equations and instead a description of the model in prose. This is perhaps a matter of personal preference, but the methodology seems less ambiguous when described with the help of equations. Early on in the model description, it should be stated that sliding is implemented and that there is some kind of thermomechanical coupling (p 6, lines 191-192). It would be useful to know a bit more about the latter without having to read Gong et al (2016).

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6: It becomes clear in the results and discussion that the HiDEM simulations do not include the change in stress state resulting from pre-existing crevasses, nor the advection of crevasses. Please emphasize these points in the methods: that the crevasses predicted by HiDEM reflect the stress field at a single snapshot in time, without consideration of any pre-existing damage or advection.

7.213-215: Suggest moving this to methods or deleting.

7. section 4.2: It would be useful to know how changes in the fracture and/or bed-penetration criteria for crevasse formation affect the mismatch between modelled and observed crevasse distributions. Were these parameters set to maximize agreement, or decided upon in advance without knowledge of the outcome?

7-8: It would really help to have some annotations of the figures to orient the reader to the geographical/morphological/dynamic regions of the domain that are referenced in the text (e.g. "margin of the subglacial valley", "northern flow unit"). Perhaps a few numbers on the figures defined in the captions would do the trick.

8.244: Reword to state that the simulated and observed crevasse maps were resampled to maximize their correlation. An "appropriate resolution" would be one chosen based on the methodology and physical principles alone, rather than one chosen to maximize agreement.

8.264-272: This paragraph seems more like discussion material.

Figure 3. Separate (a) and (b) a bit better, e.g. with a line or boxes. Figure 3 is scarcely mentioned in the text (bottom of pg 6) and no description appears to be given of the 4 panels on the right-hand side. Consider adding a sentence or two of explanation to the text.

Technical corrections/queries (page.line):

The manuscript is clear and well-written overall, but still has some incorrect or awkward English phrasing. Articles (mostly "the") are missing in multiple places throughout text,

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hyphens are missing or used incorrectly, sentences are started with "And" and past and present tenses are mixed. The native speaking coauthors should be able to improve this with a quick proof-reading.

2.61: Dunse et al (2015) "have"

3. 88: Suggest "Observations and data processing" as Section 2 title, since there is significant content related to methodology.

3. 99-100: "The sub-glacial hill. . ." not a sentence.

4. 113-126: paragraph needs proof-reading

5.162: Suggest "Modelling methodology" as Section 3 title, since section is related exclusively to modelling and methods for data processing were described earlier.

5.173: "brought by" => "due to"

7.227: "basin-wise" => "basin-wide"

7.236: Cannot see black box in southwest corner of Fig 5b.

8.245: "leaded" => "lead" or "led"

8.245-255: hard to know exactly where "northern", "middle", and "southern" flow units are in figures. It would really help if Figure 3c were bigger.

10.314: "factures" => "fractures"

11.356: "though" => "through"

11.376: What is meant by "cut in"? Started?

12. 386-387 "input" repeated

Figure 1. (a) Difficult to read the contour labels for surface elevation. (b) Need some labels or stated range of surface elevation contours. Need units for bedrock elevation (presumably m above sea level) more clearly stated. Sideways "m" on colorbar looks

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like “E”. See Figure 5 also.

Figure 2. Put (a), (b), (c) labels in a better place. Figures stretched in the vertical. Please clarify caption for panel (c). Is there a colorbar missing? It is hard to see the detail described in the text with the current size and resolution of this figure, particularly (c).

Figure 4. Some years missing on the date labels.

Figure 6. (b) “bedrock elevation is color-coded in the background”? It seems the color in (b) is described in the caption under (c), but panel (c) has been removed.

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