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Interactive comment on "Poor performance of a common crevasse model at marine-terminating glaciers" *by* Ellyn M. Enderlin and Timothy C. Bartholomaus

Anonymous Referee #1

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Summary of manuscript

This study infers crevasse depth from Operation IceBridge ATM data along swaths of 19 Greenland outlet glaciers over 6 spring campaigns, and compares these depths to the Nye formulation, a simple model for crevasse depth based on local stresses. The paper finds a systematic misfit between the "observed" and "modeled" crevasse depths: observations show consistently shallower crevasses than modeled. The authors speculate that the mismatch may originate from deformational history of the ice as well as non-uniform stress concentrations at crevasse tips. The authors conclude that the Nye formulation is inadequate for use in calving parameterizations.

Comments

The "observations" of crevasse depth presented here are flawed. The authors find a local elevation maximum, minimum, and maximum for each crevasse and calculate crevasse depth as the elevation difference – that is, they interpret the elevation minimum as the crevasse bottom. If the lidar were downward-looking, this could be a reasonable approximation; however, the ATM looks outward at $\theta = 15^\circ$ angle, never straight down, in order to increase its effective swath width (see https://nsidc.org/sites/nsidc.org/files/technical-references/OIB-ATM-transceivers.pdf, where Table 1 notes the full scan angle, which is 2θ, for off-nadir angle θ). This means that the ATM cannot see deeper than $\frac{W}{\tan\theta}$; for a crevasse $W = 10$ to 20 meters wide, the ATM depth limitation is 40–70 meters, which is consistent with the results shown in Table 1. Crevasses may well be deeper than what the ATM instrument can constrain.

Although the above limitation is not mentioned in the manuscript, the authors do seem to account for the possibility that the ATM misses the crevasse bottom by introducing their V-shape correction. It is reasonable to expect that even a downward-pointing lidar might miss a crevasse bottom, since the beam footprint is ~1 meter, and crevasse width is much narrower than this at the tip, so the beam would see sidewalls as well as bottom and give a too-shallow average elevation. The authors thus infer a truer crevasse bottom by linearly extending the slopes of each wall to the point where they meet. While I appreciate this approach, it is still an underestimate of the crevasse depth. Although the large crevasses typically found on the outlet glaciers being studied here do appear, from the surface, to have wide V shapes, it is unlikely that the crevasses terminate at the tip of the apparent V. Stress concentration at that point are high, of course, which will drive the crevasse downward beyond the V tip. Crevasse shape below the V tip will be a narrow fissure, probably meandering irregularly downwards, as often seen on smaller crevasses upglacier or in alpine environments. This is not captured by the authors' V-shape model, yet that "extra" depth is accounted for in the Nye formulation (as I understand it). Importantly, this fissure below the V tip would easily facilitate calving, which is the broad and important application of this study.

Overall, the full meaning and limitations of the observational data, described above, are not presented in the manuscript. The authors misinterpret ATM observations as crevasse bottoms, or as data that can be used to infer crevasse depths, when in fact the ATM measurements can only underestimate crevasse depths. True crevasse depths will be deeper, and may in fact compare well with the Nye formulation. The data presented here cannot support evaluation of the Nye formulation. Thus, much of the manuscript, including its title, is substantially flawed. Most of the tuning analysis, for instance, is irrelevant, given the above.

The figures were somewhat difficult to interpret. An illustration of data from a single crevasse, or from a few crevasses across a reach of a kilometer or two, would have greatly helped me understand the picking, extrapolation, and manual/automated approach. I liked the organization of the panels for each glacier within a rough map/array of Greenland (Figures 2–3), but I missed helpful features like titles, y-axis labels, and consistent y-axis ranges among panels.

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