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The Cryosphere Discussions

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

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We thank referee #1 for his or her timely and engaging review. We respond here to a couple of points that might have been under-appreciated in the referee's review of our manuscript, prior to a more complete revision and response that we plan to complete following receipt of the 2nd referee's comments. In the revision, and guided by the advice and critique of referee #1, we will be certain to strengthen the discussion of the following elements of our analysis.

First, the referee points out that the off-nadir pointing angle of the OIB laser is a potential limitation of laser-measured crevasse depths. While the referee is correct in her

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or his description of this limitation, off-nadir pointing limits measurements of crevasse depth, but does not bias our measurements of crevasse shape. If the off-nadir path of the laser beam intersects a crevasse wall or crevasse lip, it will simply not return elevation measurements of the crevasse bottom. In this sense, the off-nadir angle joins two other limitations, broken serac debris and ponded water at the bottom of crevasses, as a limiting factor in assessing crevasse depths. Thus, our analysis of crevasse morphology and the finding that crevasses are dominantly "V" shaped addresses this broader concern, since, guided by our data, we extrapolate crevasse walls to the bottom tip of the V.

Second, although the crevasses are very well-fit with V shapes, we concur with the referee that the true, maximum depth of many crevasses undoubtedly extends beneath the tip of the V as a paper-thin, englacial fracture. Thus, our measurements are minimum crevasse depths. This is a point we will make more explicitly in our revision. However, our result remains: even if we apply a scalar (either additive or multiplicative) factor to the observed crevasse depths to minimize the average bias with respect to the depths predicted using the Nye formulation, the patterns in the depths extrapolated from elevation observations and the patterns inferred from velocity fields using the Nye formulation do not agree. We find no correlation between observed and predicted crevasse depths (Fig. 4), and the spatial pattern of observed crevasse depths is unrelated to the spatial pattern of predicted crevasse depths (Fig. 5). We cannot envision some other, plausible correction factor that will bring Nye-modeled crevasse depths in line with observed crevasse depths. As ours is the most complete and thorough examination of the popular Nye model, building on the foundational work of Mottram and Benn, 2009, we believe our results are highly significant. We repeat for emphasis that our results are deeper than the finding of a systematic offset between modeled and observed crevasses. Instead, we find no relationship whatsoever.

The discrepancy in crevasse depth patterns is important because it tells us that we cannot rely on local strain rates to accurately model crevasse depths. If we use surface

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crevasse depths from the Nye model in numerical models of calving, as has been done in a number of studies, then the model may fail to capture the correct spatio-temporal evolution of terminus position. If Nye-modeled crevasses are used to route surface water to the bed, the spatio-temporal evolution of these water inputs are likely to be incorrect. We will revise the manuscript to address these points following the receipt of all reviews, emphasizing that although our observed crevasse depths may underestimate true depths, the discrepancies in the observed and modeled depths suggest that the predictive power of the Nye formulation for crevasse depths is limited when applied to the complex histories and geometries of Greenland's outlet glaciers.

We eagerly anticipate the comments of the 2nd referee, and the suggestions of the editor.

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