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The Cryosphere Discussions

Interactive comment on "Testing hypotheses of the cause of peripheral thinning of the Greenland Ice Sheet: is land-terminating ice thinning at anomalously high rates?" *by* A. Sole et al.

A. Sole et al.

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First, we would like to thank the two anonymous referees and M. Pelto for their comments and remarks on the manuscript. Below are our replies to their suggestions.

Anonymous Reviewer 1: The only point I would raise is that the assumption underpinning hypothesis 2, that marine-terminating and land terminating outlet glaciers should show the equivalent response to enhanced surface melting, isn't necessarily valid. As the authors point out, the fact that tidewater glaciers have ocean connections means that they should have lower effective pressures than land terminating margins. Therefore, an increase in meltwater penetration to the bed shouldn't necessarily effect them the same way. Anyways, Joughin et al, 2008, Science, has already clearly shown the

answer, so it is not a big deal. I would just ask the authors to explain their logic behind hypothesis 2 a bit more clearly - why should these systems respond the same way to meltwater penetration?

It is uncertain whether marine and land-terminating glaciers will have the same sensitivity to increased meltwater at the bed. Differences in effective pressures which favour an enhanced sensitivity for marine-terminating outlets may be countered by the effects of smooth beds, basal shear heating and geometry characteristic of such outlet glaciers (Joughin et al., 2008). A reasonable first assumption is therefore that marine and land-terminating outlet glaciers will respond similarly to increased meltwater at the bed. We have changed the text as detailed below.

Resulting changes to manuscript:

Page 680 (as in TCD), lines 6 - 11; 13 changed to:

"Marine-terminating outlet glaciers may be inherently more sensitive to changes in basal water pressure than land-terminating outlet glaciers since their termini are often already at or near the flotation point. Therefore, an identical increase in surface meltwater input to the bed would be more likely to raise subglacial water pressure to values approaching overburden pressure across other areas of the bed at a marine-terminating terminus, with correspondingly larger ice acceleration and dynamic thinning. If this were the case, a surface melt induced forcing also has the potential to reduce significantly once the GrIS retreats beyond the ocean. However, there may also be other factors related to ice velocity, bed roughness and glacier geometry which serve to decrease marine-terminating outlet glaciers' sensitivity to variations in basal water pressure (Joughin et al., 2008). Joughin et al. (2008), found that the seasonal summer ice acceleration for both 'ice sheet' (ice velocity $<$ 150 m yr-1), and 'outlet glacier' (ice velocity $>$ 150 m yr-1) regions on the west coast of the GrIS was fairly spatially consistent when averaged over 24 days. This suggests that dynamic thinning caused by ice acceleration is likely to be similarly uniform."

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Page 681 (as in TCD), lines 3 - 8 changed to:

"1.2.2 Hypothesis 2: Thinning is principally caused by direct meltwater effects on ice flow. This is the first mechanism discussed in Sect. 1.1. It is uncertain whether marine and land-terminating glaciers will have the same sensitivity to increased meltwater at the bed. As previously mentioned, differences in effective pressures which favour an enhanced sensitivity for marine-terminating outlets may be countered by the effects of smooth beds, basal shear heating and the geometry characteristic of such outlet glaciers (Joughin et al., 2008). A reasonable first assumption is therefore that dh/dt of land-terminating and marine-terminating outlet glaciers should be statistically the same. We test this hypothesis by comparing mean dh/dt for a number of marine-terminating and land-terminating outlet glaciers in Southern Greenland (Fig. 1). This region was chosen because there are more marine-terminating and land-terminating outlet glaciers with good flight line coverage."

M. Pelto: The main suggestion I have for this paper, if possible, is to examine the identified magnitude of thinning of the marine terminating outlet glaciers, in the context of how much effective bed pressure change this would induce.

Good idea, but we don't know enough about subglacial water pressure which is likely to change significantly. We would therefore have to assume equilibrium (i.e. water pressure in balance with ice overburden pressure), so the variations in effective bed pressure would be solely due to changes in ice thickness (ice surface elevation) which would be unrealistic.

M. Pelto: A further suggestion is that in Figures 4-6 the color coding is confusing as land and marine are not uniformly of the same color in the same diagram.

Have changed - thanks!

M. Pelto: I believe a table would be useful to more concisely delineate the observed thinning rates for each glacier between the two time periods and at one or two specific

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elevations.

Also a good idea. We have constructed tables containing mean dh/dt and maximum thinning rates for above and below 1000 m elevation for both 1993 to 1998 and 1998 to 2006. These will be included in a revised version of the text which will be submitted to TCD.

M. Pelto: Since the thinning observations focus primarily on the ablation zone, section 4.2 is not as critical and I hope it does not distract from the important lower elevations data.

This section was added as the result of a previous review in another journal. The intention was to include the effects of precipitation because this is an important control on variations in surface elevation. However, it is not particularly important in the ablation zone where thinning rates are high, and we think that this section explains our position adequately.

M. Pelto: Figure 7 is particularly important and deserves more attention.

Point taken, and this issue is discussed in the conclusion as well as the results section.

M. Pelto: Is Figure 8 warranted?

Yes, we think so. It provides an overview of the bed elevations and thus identifies outlet glaciers which may remain in contact with the ocean for longer periods.

Anonymous Reviewer 2 had no comments that required changes to the text.

References

Joughin, I., Das, S., King, M., Smith, B., Howat, I. and Moon, T.: Seasonal Speedup Along the Western Flank of the Greenland Ice Sheet, Science, 320, 781 - 783, 2008

Interactive comment on The Cryosphere Discuss., 2, 673, 2008.