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Interactive comment on "Are seasonal calving dynamics forced by buttressing from ice mélange or undercutting by melting? Outcomes from full-Stokes simulations of Store Gletscher, West Greenland" *by* J. Todd and P. Christoffersen

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We are very grateful for the positive and constructive feedback from the anonymous reviewer. We address the reviewers points in turn below, with original comments in black and our responses in red.

I think that overall this is a fine paper, easy to follow, well written and clearly documented. It makes a significant contribution to the overall question of how ice melange

and marine terminus undercutting by melting along the calving face exposed to the ocean influence calving rates and retreat or advance of Greenlandic outlet glaciers. I don't think that the study settles any issues, but it still provides important knowledge and experience on the subjects. I also think that it may be that a false dichotomy is being implied without intending to be implied: is it really fair to say that ice melange back stress is more or less important than marine face undercutting? The two processes both have the potential to be important, and is it really fair to imply that they are in "competition"? As the paper clearly points out: the results hold for Store Glacier most precisely and may not apply to other situations. This might be pointed out more emphatically in the abstract (if it is not).

This is a fair point; while it was not our intention to imply that the processes of mélange buttressing and submarine melting are in direct competition, the choice of wording in the abstract may imply this. We have modified the abstract (p.3526,l.7-8) to read **"On the other hand, the effect of submarine melting on the calving rate of Store Gletscher appears to be limited."** as opposed to **"secondary role"** which may imply competition between the two processes.

- page 3529, line 23 - "annual formation and collapse" of melange. What is specifically meant by formation and collapse? e.g., does collapse mean "dispersal" or does it mean something else, and does formation mean that a previously empty fjord is then filled with icebergs?

  We are principally interested in the presence of *rigid* mélange. We have modified the text (p.3529,l.23-25) to clarify this:

  "The glacier is buttressed by a rigid proglacial mélange, which is typically present from late January or early February to the end of May (Howat et al., 2010). When present, this rigid ice mélange has been shown to exert a significant backstress on the calving terminus of Store (Walter et al., 2012)."

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- page 3535 line 25 - why is it necessary to apply a scaling factor? How would results change if no scaling were done?

  We discuss the need for this scaling factor in Section 3.4, p.3535,l.13-24. Without the application of the scaling factor, the terminus continues to advance indefinitely into the fjord. We would emphasise, however, that the scaling factor used here is small compared to previous studies using crevasse-depth based calving models (Nick et al., 2010, Vieli and Nick, 2011), as discussed on p.3535,l28-p.3536,l2.

- Just a strange comment: The Norse were in Greenland before the Inuit. The Inuit apparently replaced the Dorset people who the Norse found in Greenland when they arrived before the Inuit. (At least, this is what I have heard or read.) So, is it really fair to use an Inuit word for ice melange rather than an Indo-European word? In fact, if there were to be appropriate attribution to the original native languages of Greenland, would an Icelandic term (representing a close approximation to Norse of Greenland) be better than both ice melange and sissusak? Is there a Dorset word for the same type of ice? Anyway, something that occurred to me now and then. . .

  Interesting comment! A brief search didn't reveal much info about what the Dorset people might call it. Previous studies have opted for either "ice mélange" (Amundson et al., 2010, Walter et al., 2012) or occasionally "sikussak" (Dowdeswell et al., 2000, Ryan et al., 2014). Here, we opt for the former which, being French, presumably falls under the broad heading of 'Indo-European'.

- Out of curiosity: Is it possible that bending moment at the ice front (due to sea water pressure alone) could cause the calving face to become non-vertical? If so, how does the rate of rotation of the vertical face due to bending moment of sea water compare to the effective rotation rate caused by a typical ice-front melting profile?

  The stress situation at the calving terminus of Store Gletscher is quite complex.

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There is the persistent outward and downward bending moment, typical of calving glaciers, which results from the imbalance between the ice cliff and sea water pressure at the face itself. Counteracting this, there is an upward bending moment acting on the base of the floating section of the terminus; this is due to the glacier flowing downhill into the sea, below the level of neutral buoyancy, faster than ice creep allows it to adjust upwards. As such, the overall bending moment is difficult to ascertain, making the question difficult to answer. One might expect, however, that in the general case, this forward bending moment most likely results in the toppling of the subaerial seracs, followed by submarine calving events, before a significant slope in the calving front could form.

- This wasn't clear to me at about page 3541: Does the model predict "ice melange formation"? or is the presence or absence of ice melange as a boundary condition on the ice front independent of what calving is actually happening at the ice front in the model?

  Our model focuses solely on the flow dynamics and response of the glacier itself. As mentioned on page 3538:l1-7 we use the observations of Howat et al. (2010) to *prescribe* the presence or absence of ice mélange through the year, and those of Walter et al. (2012) to constrain the magnitude of the buttressing force.

- page 3542: in the discussion, is it fair to say that submarine (presumably on the vertical or nearly vertical ice front) is "less important" in all cases of all possible glaciers? . . .or is this a result that could be more or less specific to the regime of the Store glacier? Is it possible to evaluate how representative the results of the present study are in determining a generality about the relative importance of the ice melange vs the submarine melting? I see that this is somewhat answered on the next page. . .

  We don't claim that submarine melting is less important than mélange for all possible glaciers. On the contrary, we interpret our results from Store as a reason

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this glacier has remained stable while others have retreated, and on page 3543 line 12 we state that this feature is most likely "specific to Store" in order to avoid implying that our results necessarily extend to other glaciers.

As to broader applicability of our results, Store Gletscher is characterised by its fast-flow and strong topographic control. We might expect Store's characteristic "melt insensitivity" to be shared by other glaciers with similar topographic control. Although many glaciers have retreated, there is a growing body of evidence for contrasting behaviour of neighbouring glaciers (e.g. Moon et al., 2012). However, given that we presently only investigate Store itself, we feel that to make any more general claims in the paper would be overreaching.

Interactive comment on The Cryosphere Discuss., 8, 3525, 2014.