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The Cryosphere Discussions

Interactive comment on "Mechanical effect of mélange-induced buttressing on embayment-terminating glacier dynamics" *by* D. Seneca Lindsey and T. K. Dupont

Anonymous Referee #1

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tc-2012-146 *"Mechanical effect of melange-induced buttressing on embayment-terminating glacier dynamics"* - **D.S. Lindsey and T.K. Dupont**

This paper presents the setup and the application of a model with the objective of explaining the influence of ice mélange on ice calving, and consequently on the overall flow of the upstream ice-stream. Ice mélange, by reducing calving rate during winter allows the glacier front to advance. As a result, less or weaker mélange would result in an increase of calving and consequently in an increase of ice flux to the ocean.

To demonstrate this idea, the authors are using a shallow shelf (or shallow stream) type model assuming a continuous medium for the ice-stream and the ice mélange. The only difference between these two materials is that the ice rheology of the ice-stream is $\approx$36% larger than those of the mélange.

I think the broad idea discussed in this paper is well admitted, and relatively easy to figure out, without even the use of any model. The point is that if one wants to go further, which is the aim of this paper, and try to quantify the real effect of ice mélange (which advance of the front can be expected, which seasonal variation of calving rate, . . .), the proposed model is by many purposes not adapted to this objective.

Thickness use for the ice mélange

Ice mélange is a composite material made of icebergs, parts of icebergs and sea ice. Even if there is not that much observations, ice mélange is certainly a very heterogenous material, and at the zero oder, this heterogeneity can be described by the mélange thickness heterogeneity. It is well known that sea ice, because of its very low heat conductivity, starts growing very slowly after few meters, so that sea ice thickness stays below $\approx$3 meters. Even if small in area, sea ice is therefore the weak part of the ice mélange, and therefore determines the maximum resistance that can be expected from ice mélange. If using a continuum approach, as in this paper, the ice mélange thickness should then be set to a value much smaller than the $\approx$200 meters used here. In other words, the study should only discuss results obtained with mélange value lower than 0.3%, two orders of magnitude smaller than the value used here for the discussion.

Calving law and other processes

The calving law used in this model is only phenomenological and is not enough physical to describe the mechanisms at the root of calving rate decrease for decreasing ice mélange weakness. For a realistic ice mélange thickness (few meters), the calving rate decrease induced by the ice mélange obtain from this law would just be insignificant. A more realistic law for calving should be used or formulated for this purpose. But in any case, it cannot justify the use of an ice mélange thickness of few hundreds of meters. Moreover, the authors don't discuss the other potential seasonal processes that can decrease calving rate: there is less water in crevasses during winter, air temperature is lower, ... Ice mélange is certainly not the only contributor for the decrease of calving rate during winter, and other processes should be accounted for, or at least discussed. Ice mélange has certainly not only the effect of decreasing the strain-rate. It might also decrease the influence of tide and oceanic currents, and changes the sea water circulation at the calving front, leading to at least three other potential ice mélange induced processes that can contribute for a decrease in calving rate. This should be at least discussed in the paper.

Boundary conditions and sea water pressure

I think the model needs five boundary conditions and not four. The hydrostatic water pressure has to be applied on the part of the ice-shelf front below the ice mélange, and not only at the front of the ice mélange. There is clearly a missing force in the system if this pressure is not accounted for. The response of the model for a very small ice mélange thickness should be equivalent to the flow of an ice-shelf without ice mélange. Did you check this? In total, whatever the ice mélange thickness, the resultant force exerted by the sea water pressure on both the ice-shelf and the ice mélange fronts should be the same. So, a modified form of Eq. (5) has to be applied at the shelf-mélange transition.

I did try to reproduce the 6 km/a velocity at $x = 7.5$ km with a SSA model. With a 7.5 km long ice-shelf without ice mélange, I get a much larger velocity. I get a 6 km/a velocity at $x = 7.5$ km only for a 14 km long ice-shelf. My feeling is that you applied Eq. (5) only at the ice mélange front but with $h = 1100$ m whatever the ice mélange thickness. I think this is wrong, and especially when looking for the strain-rate transmission from

the ice mélange to the ice-shelf.

Other minor remarks

End of page 4126: why not looking at the limit case with no ice mélange by only modelling the ice-shelf alone?

Page 4127, line 21: I'm wondering how strong is this hypothesis since you are observing strain-rate at the front which is less than seven ice-thickness far from the inflow boundary (and the width of the domain is of the same order). If there is friction on the lateral side, the horizontal velocity in the flow direction is not expected to be laterally constant.

Page 4127, line 22: a non linear friction law for the x-directed flow... f is not defined and should appear somewhere in Eq. (1)? Is the value of B_s vertically integrated or is it integrated afterward in the equation? Since you gave no units for B_s, I couldn't check.

Table 1: H and not h. Units should be given for B_s. The inlet velocity is denoted u_0 in the text. I think the exponent 0.96 in the units of c_a should be 0.98.

Fig. 1, bottom: one can see on this figure that the ice shelf front is partly in contact with the ocean and thus a water pressure has to be applied.

Fig. 3, label should be calving rate and velocity.

There are clearly missing references. The author should present more deeply what is ice mélange from previous publications (e.g., Fricker et al., 2005 ; Herdes et al., 2012) and recent works on calving law (e.g., Amundson and Truffer, 2010 ; Levermann et al., 2012).

Interactive comment on The Cryosphere Discuss., 6, 4123, 2012.