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Interactive comment on "Modelling environmental influences on calving at Helheim Glacier, East Greenland" *by* S. Cook et al.

S. Cook et al.

sue.cook@unis.no

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We would like to thank Dr. Colgan for his interest in our paper. We hadn't previously considered the relationship between ice cliff height (defined by Dr. Colgan as the maximum height of a glacier's calving face above sea level) and calving rate in the model, so it was interesting to look back over the results and address this question. Dr. Colgan refers to both ice cliff height and relative crevasse depth as interesting parameters to examine. If we define relative crevasse depth as the ratio of crevasse depth to ice cliff height we find that at the terminus there is only small variation in this ratio, which remains close to 1 throughout most model runs. If we instead take an average over a slightly wider horizontal extent, the precise value depends strongly on the shape of the crevasse field, which is very variable and affected by relatively small changes in ice

geometry and hence strongly affected by the underlying bed topography. Although this variable could influence calving rates, the relationship is likely to be highly complex and we considered that the strong dependence on bed topography would make it difficult to extract any meaningful conclusions. Therefore we continue examining only the ice cliff height.

Examining terminus position and ice cliff height together, the most obvious feature is a an opposing saw-tooth pattern in the evolution of the two properties, caused by periods of glacier advance interspersed with calving events. An example of a seasonal experiment from our Discussion paper is shown in Fig. 1, with summer maxima in undercutting and crevasse water depth of 5000 m/a and 30 m respectively. Typically in our experiments, the ice profile becomes thicker up-stream of the calving front; therefore, a calving event produces an instantaneous terminus retreat and simultaneous increase in ice cliff height. Figure 1 also shows that during periods of advance in the model, the height of the ice cliff decreases (e.g. at timestep 650 & 900). This is because the advance is too quick for the ice thickness to be maintained by draw-down of ice from up-glacier, causing thinning of the terminus.

To further examine the behaviour of ice cliff height during glacier retreat, we include results from an additional experiment, published in Cook (2012). This experiment uses a constantly applied crevasse water depth (c.w.d.) of 30 m with no seasonal variation, which induces a rapid retreat of around 20 km over a period of less than a year (Fig. 2). Although this experiment produces a consistent and roughly steady retreat between timesteps 350 and 750, the behaviour of the ice cliff height shows no clear pattern, though there is some correlation with bed depth. We interpret this as showing that during rapid retreat the model has insufficient time to dynamically adjust to the high calving rate, and the ice cliff height is determined by the previous up-stream ice thickness (in a similar manner to the saw-toothed pattern observed above).

Dr. Colgan refers to previous work which indicated that ice cliff height would be a good boundary condition for calving rate at Columbia Glacier (Colgan et al., 2012).

Columbia Glacier has retreated approximately 18 km over the last 30 years, producing a type of steady, consistent retreat which we were not able to reproduce using our model of Helheim Glacier. Unlike our unrealistically rapid retreat, this type of retreat should allow the glacier time to dynamically evolve in response to higher calving rates. Our experiments give some indication that this might lead to a correlation between ice cliff height and calving rate; in many of our experiments, if the terminus position stabilised after a period of retreat the ice cliff height began to decrease (e.g. Figure 1 at timesteps 530, 760 and 1010, and Figure 2 between timesteps 100 and 350). This indicates to us that if a retreat were slow enough to allow dynamic readjustment of ice thickness, it might be accompanied by a steady decrease in ice cliff height.

From our experiments overall we are not able to derive a simple relationship between the ice cliff height and terminus retreat. Figure 3 shows the results of linear fits to terminus position and ice cliff height against time, performed separately on results from each season in each of the experiments presented in the Discussion paper. In general, the gradients of change in terminus position and ice cliff height over time are opposite (i.e. retreating experiments show thickening termini and vice versa), but the correlation is not strong. We believe that there is evidence in these model results that a steady retreat of a tidewater glacier might be accompanied by a decrease in ice cliff height, but that this relationship is likely to break down if changes in terminus position happen too rapidly to allow the ice thickness to dynamically adjust. Plotting change in terminus position and ice cliff height over time, the scatter of the results in Fig. 3 also suggests that any short term relationship between the two variables is likely to be influenced by other factors such as bed topography.

References

Colgan, W., Pfeffer, W. T., Rajaram, H., Abdalati, W., and Balog, J.: Monte Carlo ice flow modeling projects a new stable configuration for Columbia Glacier, Alaska, c. 2020, The Cryosphere, 6, 1395-1409, doi:10.5194/tc-6-1395-2012, 2012.

Cook, S.: Environmental controls on calving in grounded tidewater glaciers, Ph.D. thesis, Swansea University, 2012.

Interactive comment on The Cryosphere Discuss., 7, 4407, 2013.

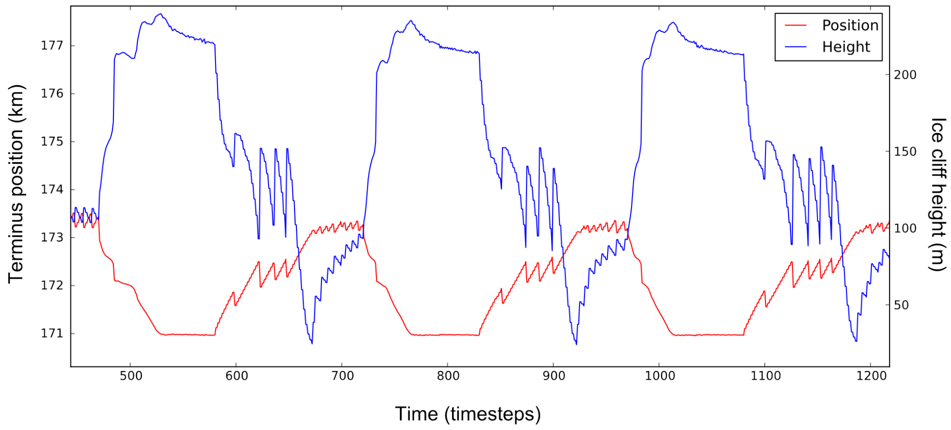

Fig. 1. Results from experiment using seasonally varying undercutting rate and crevasse water depth, with summer maxima of 5000 m/a and 30 m respectively. The time shown is equivalent to just over 3 years.

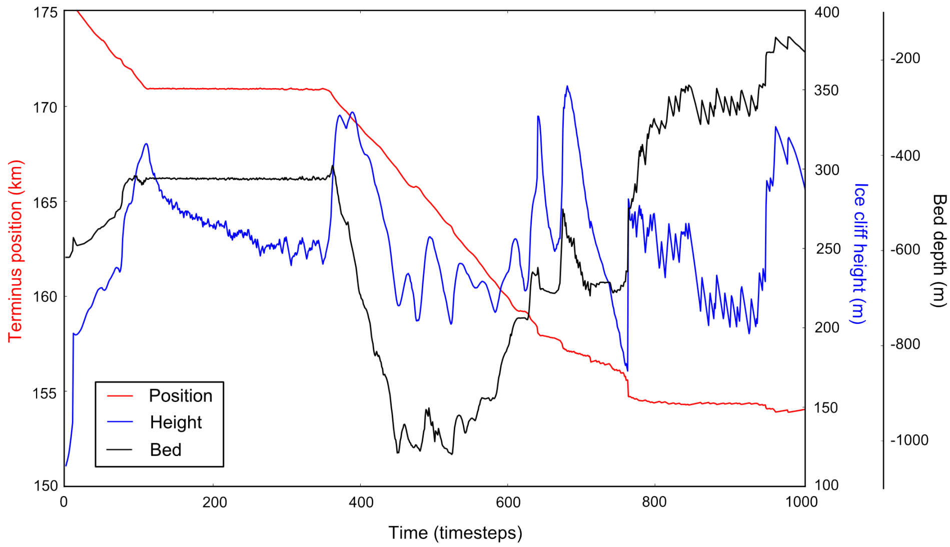

Fig. 2. Model run with constant application of 30 m c.w.d. This produces a retreat far in excess of any presented in the Discussion paper. The time series shown is equivalent to roughly 1.5 years.

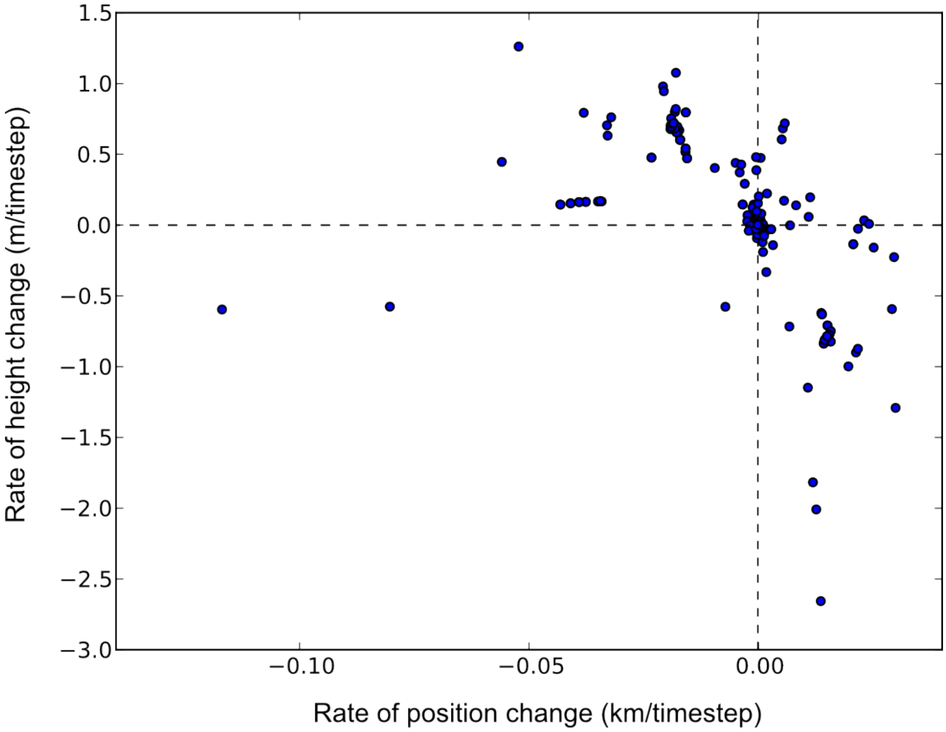

Fig. 3. For each season in each experiment in the Discussion paper, the scatter plot shows the gradient of linear fits to the terminus position and ice cliff height against time.