INSTABILITY OF A CALVING GLACIER TERMINUS

By Steven M. Hodge
(U.S. Geological Survey, Tacoma, Washington 98402, U.S.A.)

Abstract. An unstable situation can develop when a calving glacier (one that ends in water but is still grounded throughout) terminates on a shoal. This instability is largely a consequence of continuity and the extending flow which occurs up-glacier of the shoal. Whenever the calving-rate exceeds the ice velocity the ice front will start to retreat; the rate of retreat is accentuated by the extending flow and the front continues to retreat at an increasing rate.

The response of the terminus to sinusoidal seasonal variations in ice velocity and calving-rate was calculated for a simple one-dimensional model, assuming that the ice thickness does not vary with time, all the ice motion over the shoal is due to sliding, the surface ablation is constant, and the front cannot advance beyond the shoal. Surface and bed profiles and numerical values of ice velocity and ablation were chosen to approximate conditions observed at Columbia Glacier, Alaska. Three response modes were found. In the stable mode the terminus never recedes from the top of the shoal. In the permanently unstable mode the terminus recedes so far initially that it is unable to regain the top of the shoal during that part of the year when ice velocity exceeds calving-rate. In the temporarily unstable mode the terminus only recedes slightly and is able to regain the top of the shoal within a year. This gives a crude explanation of the seasonal embayments which form in late summer on Columbia Glacier. The theory predicts the correct timing of the embayment formation but does not explain their two-dimensional nature, nor their formation anywhere along the ice front. The transition from temporarily to permanently unstable mode is very sensitive to changes in the various parameters; embayment formation may thus indicate that a "catastrophic retreat" of the terminus is imminent.

DISCUSSION

O. Orheim: Your southern embayment shows progression up-glacier from 1974 to 1977, suggesting that the calving bay has a memory effect and is causing increased flow from the sides into the bay. Perhaps an explanation for other bays is that once a small bay begins to form—at any arbitrary place—then it can increase to a larger bay by increased flow, and in this case there may not be a systematic explanation for the bay location.

S. M. Hodge: Yes, this is indeed a possible explanation. In fact, qualitative observations in the field suggest that there is an increase in surface slope in towards the embayment.

G. de Q. Robin: Have you attempted to take surface ablation into account over the rapidly shoaling terminus area of Columbia Glacier? There may be a link between high surface ablation and low forward velocity in summer, which suggests that in spite of difficulty of obtaining surface ablation figures it may be as important as calving in relation to stability.

Hodge: No, not yet. We are attempting to obtain some data this summer, but it is difficult to do so in the terminus area. Ablation may have little effect since the ice thickness is hundreds of metres.

W. H. Mathews: Do you have any idea from, for example, relative rates of ice velocity and retreat by calving as an embayment develops, on the relation between calving rate and water depth?

Hodge: No, not yet. We are obtaining such data this summer from as many calving glaciers as possible.

https://doi.org/10.3189/S0022143000015124 Published online by Cambridge University Press