1 Volume time scales

With a few additional assumptions (compared to the script), you can calculate the volume time scales of real glaciers!

Glacier volumes and areas are not independent, but follow (not strictly) a scaling relation due to self-similarity. This relation is usually written as

$$V = cA^{\gamma}$$

with a theoretical exponent $\gamma = 1.36 \ldots 1.4$ (Bahr et al., 1997; Lüthi, 2009).

a) Effective ice thickness With the above equation, calculate the effective ice thickness H_e defined as $H_e^{-1} := \partial A/\partial V$ as a function of A (this will be used to calculate the volume time scale according to Equation (3.17)). **Hint**: Begin by writing A as function of V and then take the derivative.

b) Volume time scale Assuming a constant mass balance gradient $\dot{g}$ (see last week's exercise), show that the Harrison volume time scale τ_{v_H} is inversely proportional to $\dot{g}$. You can call the vertical extent of the ablation area $Z^{\star}$.

What can you say about the volume time scale of glaciers of different size (length)?

c) Using your own words and a sketch, explain the meaning of the partial derivatives in Equation 3.15 of the course script. For an ice sheet bounded by the ocean on all sides, what can you say about the relative magnitudes of the two partial derivative? Do ice sheets loose mass exclusively via iceberg calving?

2 Estimating a Glacier's Bed Profile

Download the matlab and data files from the course web page. Execute the matlab code "u2.m" making sure that all plots are generated. Familiarize yourself with the code paying attention to comments marked with "***", which indicates parameters that should be changed and played with. To back up your answers to the following questions, you can submit printed plots and pieces of code.

a) Literature Download and read the manuscript by Farinotti et al. (2009).

b) Influence of parameters In the matlab code, investigate the effect of variations of the correction factor C and the apparent mass balance gradient. Which one has a stronger influence on the bed profile estimations?

c) Influence of numerical implementation Implement a different criterion to determine the glacier surface area, which contributes to the volume flux calculated for each flowline coordinate. Similarly, calculate the surface slope in a different manner and see how its roughness/smoothness changes the bed profile estimation. Which other improvements to the numerical implementation can you think of?

d) Equilibrium line altitude As specified in the matlab script, find a value for this quantity. Explain what you did and why.

e) Discussion Discuss how portable the approach by Farinotti et al. (2009) is to other glacier catchments. Is this a means to estimate glacier volumes for entire mountain ranges, continents or the entire earth? If you challenge one or more of the method's assumptions, then explain why this is a significant shortcoming. Your answer should be concise and not exceed 1/2 page.

References

Bahr, D. B., Meier, M. F., and Peckham, S. D. (1997). The physical basis of glacier volume-area scaling. *Journal of Geophysical Research*, 102(B9):20355–20362.

Farinotti, D., Huss, M., Bauder, A., Funk, M., and Truffer, M. (2009). A method to estimate ice volume and ice thickness distribution of alpine glaciers. *Journal of Glaciology*, 55(151):422–430.

Lüthi, M. P. (2009). Transient response of idealized glaciers to climate variations. *Journal of Glaciology*, 55(193):918–930.