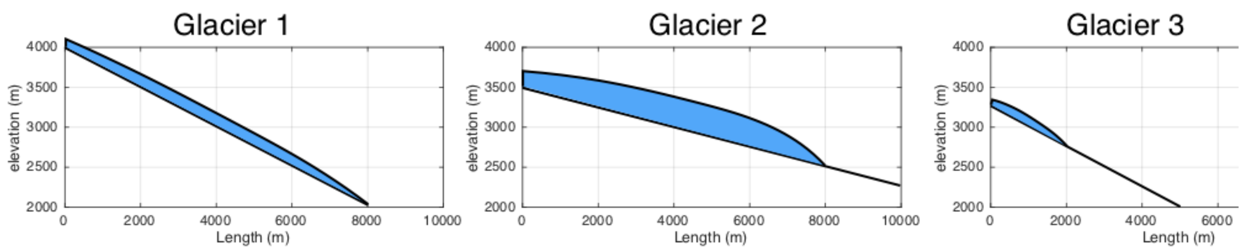
EARTH AND SPACE SCIENCE **Autumn 2018**
431 *PRINCIPLES OF GLACIOLOGY* 4 Credits, SLN 14855
505 *THE CRYOSPHERE* 4 Credits, SLN 14871

Lab Week 6 – Glacier Variations

I. Glacier Equilibrium Response to a Change in Climate

Consider three simple glacier geometries. Assume they reside in the same climate, all with an Equilibrium Line Altitude (ELA) of 3000m, and mass balance gradient $\frac{db}{dz}$ of 8 (m/yr)/km. All have constant widths.



- Glacier 1 starts at an elevation of Z = 4000m and terminates at 2000m. Its steady state length, L_0, is 8000m. Its characteristic thickness is 80m.
- Glacier 2 starts at an elevation of Z = 3500m and terminates at 2500m. Its steady state length, L_0, is 8000m. Its characteristic thickness is 160m.
- Glacier 3 starts at an elevation of Z = 3250m and terminates at 2750m. Its steady state length, L_0, is 2000m. Its characteristic thickness is 75m.

1) Find the response times and equilibrium sensitivities (dL/db) for each glacier. See if you can arrive at a compact symbolic expression for equilibrium sensitivity (valid for these simple geometries). You'll need it later.

2) You are doing fieldwork on glacier #2 and, on your lunch break, ski over a small pass and find another glacier on the same mountain. You're at the head of the glacier, which your GPS tells you is at 3200m. You can see that it has the same slope, and assume being close by and same aspect, it has the same mass balance gradient and ELA. But, it's a bit cloudy down below so you can't see the terminus.
   a. Estimate the new glacier's length and terminus elevation from what you know about glacier #2.
   b. You don't know the thickness of this new glacier, but using what you know about glacier #2, estimate this glacier's response time and sensitivity.
   c. Given what you know about ice dynamics, explain why you think this estimate is likely an over or under estimate. You don't have to solve for the thickness, but explain the physical basis for your answer.
   **hint: think about last homework on kinematics and dynamics*

II. Glacier Transient Response to a Change in Climate

The simplest model for transient response is exponential (as discussed in reading and homework). The transient length solution for trend in mass balance ($\dot{b} \equiv \frac{db}{dt}$) starting at t = 0 is:

$$L'(t) = \frac{L_0}{b_t}\dot{b}\left[t - \tau\left(1 - e^{-t/\tau}\right)\right]$$

where b_t is the mass balance rate at the terminus and τ is the glacier's response time.

1) If glaciers 1—3 are subject to the same trend of -0.005 (m/yr)/yr, after 100 years how far out of equilibrium are they? (solve for the length difference between transient and equilibrium responses).

2) Is the difference due to their different response times or different sensitivity? To find out, modify your expression for equilibrium sensitivity from part I so that it expresses the equilibrium response to a trend as a function of time. Then, divide the transient response (above) by the equilibrium response to get an expression for *fractional adjustment.*

3) What does it depend on? What is it for each glacier, after 100 years?

4) Now, consider two more glaciers. We don't know their mass balance gradients or sensitivities. But we do know their response times (10 and 50 years), and have observed both retreat 800m in the last 100 years. If we again assume a mass balance trend started 100 years ago, estimate how far each of these glaciers would retreat if the mass balance trend stopped today.