The goal of this problem set is to get everyone on the same page with basic mathematical description of a glacier. These problems will draw on van der Veen Chapter 1, some mathematical background from other courses, and concepts we discuss in lecture.

Problem 1. [2 pts] For each of the following, write whether it is a scalar, vector, or tensor variable and how you know.

- Glacier velocity
- Cauchy stress
- Crevasse depth
- Hydrostatic pressure
- Surface mass balance
- Change in glacier front position

Problem 2. [2 pts] Notation: write out each of the following expressions in the notation given in van der Veen.

(a) The derivative of the x-component of velocity in the x direction

(b) The components of the strain-rate tensor $\dot{\varepsilon}_{ij}$ (see Equation 1.34)

Problem 3. [3 pts] Leigh and Denis are monitoring the motion of Helheim Glacier. In March, they place two GPS stations on the ice surface, one at point A and one at point B. In December of the same year, a transmission shows that the stations have moved to locations A' and B'.

Find:

(a) The displacement vectors $\overrightarrow{AA'}$, $\overrightarrow{BB'}$.

(b) The velocity vectors of stations A and B

(c) The average speed recorded at the two stations over the period

Problem 4. [3 pts] Consider the idealized glacier drawn below. It has a constant mass balance gradient α, such that the mass balance $a = \alpha(h - z_0)$ is positive above the equilibrium line elevation and negative below.

(a) Assuming the glacier is in equilibrium with its surroundings (no net flux in or out), write an equation for its conservation of mass.

(b) How does this change if we assume that the glacier is not in equilibrium? For example, say that there is a net annual mass loss from the system?

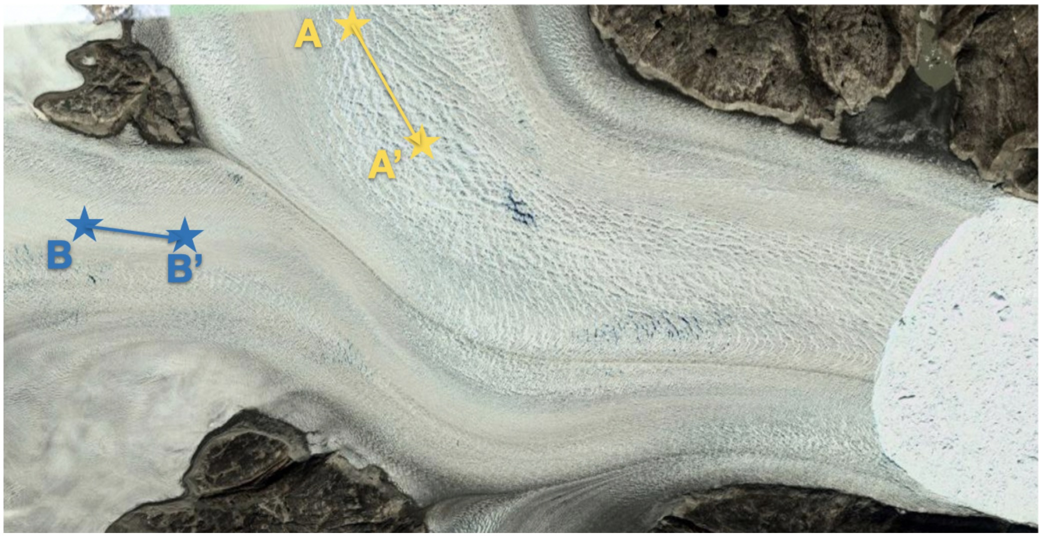

Figure 1: Stations A and B on Helheim Glacier. Positions, in kilometers easting and northing, are A: (298, -2573); A': (300, -2578); B: (295, -2578); B': (297, -2579).

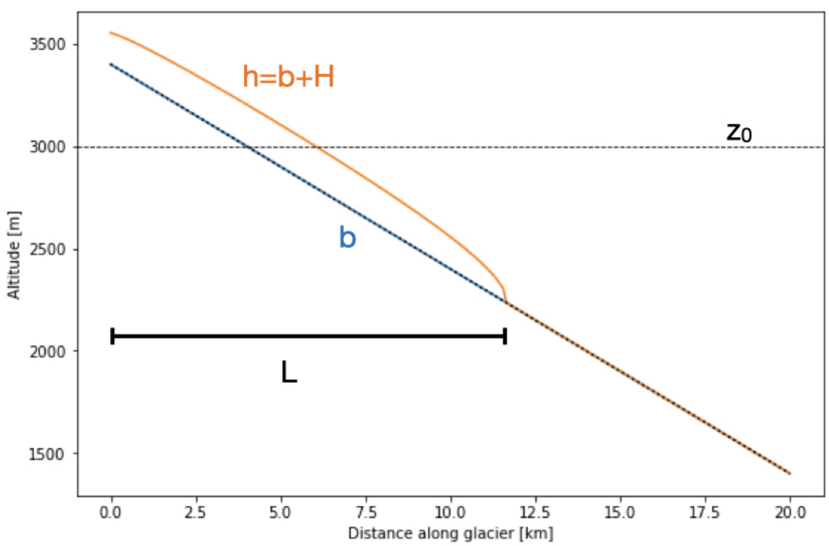

Figure 2: An idealized glacier of length L with bed elevation b, surface elevation h, ice thickness H, and equilibrium line elevation z_0. You may assume the width is constant and treat the problem along the cross-section shown.