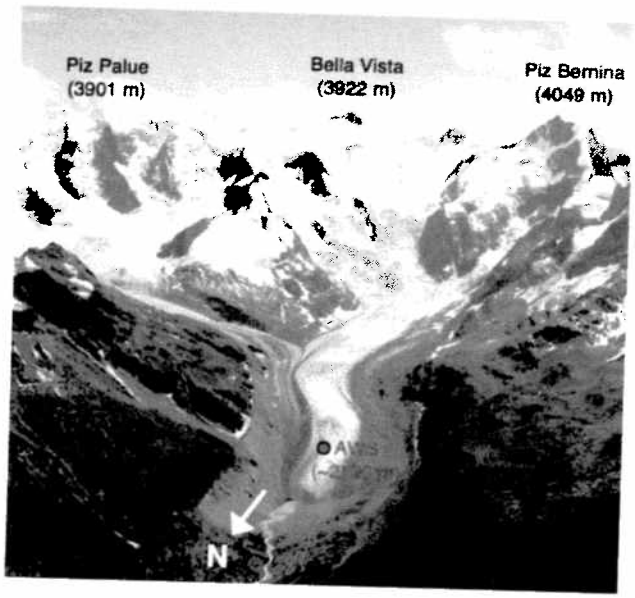
Examination **ICE AND CLIMATE,** 18 March 2013 (retake), 14:00-16:30

1. Measurements with an Automatic Weather Station (AWS) on the snout of the Vadret da Morteratsch have shown that in the long-term mean only about ¼ of the extra-terrestrial irradiance is absorbed at the glacier surface.

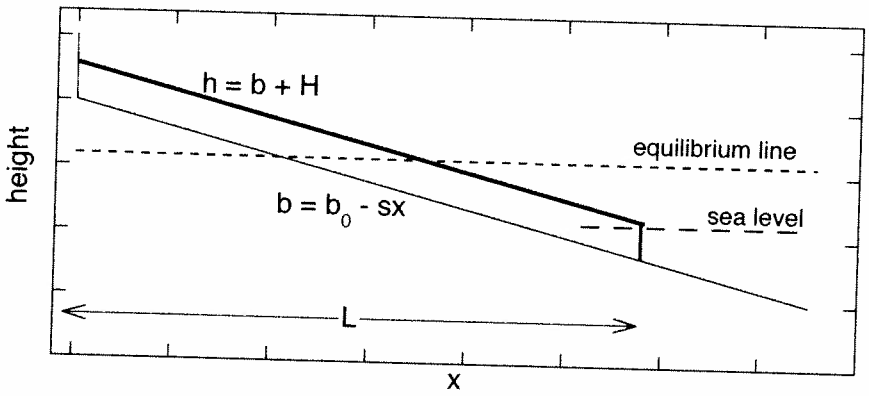
a. Describe the processes that are responsible for the 'loss'.

Measurements also show that the wind blows persistently down-glacier (the 'glacier wind'), irrespective of the large-scale circulation.

b. What is the mechanism driving the glacier wind and how does it affect the mass balance?



2. We consider a simple model for a calving glacier of constant width, having a constant thickness H and flowing on a bed $b(x)$ with a (small) constant slope s: $b = b_o - sx$. Water and ice density are denoted by ρ_w and ρ_i, respectively. There is no floating ice tongue, i.e. calving occurs as ice reaches flotation.



a. The maximum possible glacier length is $L_{\max}$. Find an expression for $L_{\max}$. Note that L is the glacier length in the x-direction (not along the bed).

The surface balance rate is written as $\dot{b} = \beta(h - E)$. Here β is the balance gradient and E the equilibrium-line altitude. The calving rate at the glacier front is proportional to the water depth (constant of proportionality c).

b. Solve for the equilibrium solutions of L as a function of E.

c. Make a qualitative sketch of the solution $L(E)$.

3. An approximate force balance for an ice sheet - ice shelf system can be written as

$$-\rho g H \frac{\partial h}{\partial x} + \frac{\partial}{\partial x}\left(2 H \overline{\tau'_{xx}}\right) - \tau_b = 0$$

This equation describes the balance of forces acting on a column of ice.

a. Explain briefly what the terms in this equation actually represent.

An ice shelf floats in a sea with water density ρ_w.

b. How can the equation above be simplified for an ice shelf ?

c. Show that the longitudinal stress deviator reaches a minimum value close to the front of the ice shelf.

In recent years large ice shelves have been broken up in the Antarctic Peninsula (Larsen Ice Shelf).

d. What is considered to be a likely explanation for this rapid break-up ?

4. There are several theories about the causes of the Pleistocene glacial cycles. In some of these theories insolation variations related to changes in the orbital parameters of the Earth play an important role.

c. Describe the orbital parameters and explain how they affect insolation.

d. The orbital effects are not synchronous for the northern and southern hemisphere. Nevertheless, there is abundant evidence that ice ages in the northern and southern hemisphere occur simultaneously. How can this be explained?