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In 2005/2006, the course NS-MO427 was given by J. Oerlemans.

Ice and Climate (NS-MO427)
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Question 1 *(2.5 points)*

The assumption of perfect plasticity is very useful to derive the profile of an ice sheet $H(x)$ on a flat (horizontal) bed [H is the ice thickness].

a) Describe the concept of perfect plasticity.

b) Derive the expression for the profile of a perfectly plastic one-dimensional ice sheet of length L. The yield stress is τ_0. Assume that the edge of the ice sheet is at $x = 0$. There is no isostatic adjustment of the bed. Denote ice density by ρ_i.

c) Relate the mean surface elevation of the ice sheet to its size L.

d) The mass balance is given by $\dot{b} = \beta(h - E)$, where β is the balance gradient, h is the surface elevation and E the equilibrium-line altitude. Construct a solution diagram for the ice sheet, i.e. make a graph that shows the equilibrium states in dependence of E.

Question 2 *(1.5 points)*

The glacier microclimate is characterized by katabatic winds.a

a) What is a katabatic wind?

b) Describe how katabatic winds affect the mass balance of a glacier.

Question 3 *(2 points)*

Ice cores form a unique archive of paleoclimatic information.

a) What is the best location on an ice sheet to drill an ice core? Motivate you answer!

b) An interesting aspect is that one can analyze temperature change (stable isotopes in the ice) and atmospheric composition (enclosed air bubbles) in the same core, and therefore study the relation between climate forcing and response. But there is a major problem here. Which one? Can it be handled?

Question 4 *(2.5 points)*

An approximate force balance for an ice sheet – ice shelf system can be written as

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

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

a) Explain what the three terms represent.

b) How can this equation be simplified for an ice shelf?

c) An ice shelf floats in a see with water density ρ_w. Relate the longitudinal stress deviator to the ice thickness.

d) In recent years large ice shelves have been broken up in the Antarctic Peninsula (Larsen Ice Shelf). Can you give an explanation for this rapid break-up?

Question 5 *(1.5 points)*

In the history of the earth over the past hundreds of millions of years, periods of continental drift, orogenesis and variations in atmospheric carbon dioxide had a profound effect on the climatic state. Can you describe what type of conditions could favour the built-up of continental ice sheets and the presence of relatively cold climates?