The effect in the ice—assuming temperate ice with a certain water content—is a positive temperature anomaly around the channel, in accordance with the stress field. The radial temperature profile in the ice around a conduit with a circular cross-section follows directly from the solution for the stress field, and the heat flux can be deduced, allowing for the ice flow towards the conduit. Pressure changes in the conduit cause a rapid change of temperature (with an associated change in water content) and a related change in heat and ice flow. In the case of a channel or cavity at the glacier bed, the temperature fluctuation produced in the channel and the surrounding ice propagates into the substratum. With rising water pressure, i.e. falling temperature, the substratum becomes a heat source and some melting will occur at the ice/rock interface in a fringe zone around channels and cavities. It is this process which may help to explain the increased sliding component of glacier motion at the time of high melt-water run-off.

Another intriguing question is what happens in a highly permeable substratum (shattered rock, moraine) at some distance away from a channel. The temperature profile is determined by the pressure melting point within the glacier down to the bed, and the positive geothermal gradient with increasing depth in the substratum below. The water pressure in the substratum is approximately equal to that in the channel, that is to say well below the mean pressure at the glacier bed. There is therefore an uppermost layer of the substratum at a temperature below the freezing temperature of the interstitial water, implying that the water must be frozen in this layer. This is one way to look at the problem. Starting out from the impermeable frozen layer it may be argued that the water film at the glacier bed is at a high pressure and the interstitial ice should melt until the water breaks through at the lower freezing boundary. This could only happen where and as long as there is no appreciable drainage of the water film and interstitial water. As soon as the water breaks through, the pressure will drop and presumably just enough leakage will be sustained to lead to a pressure drop across the frozen layer in accordance with the temperature profile. A generally impermeable glacier bed results as a most likely model, with permeable bands along subglacial drainage channels and eventual leakage holes in between. Taking the pressure fluctuations into account, one finds that temperature fluctuations have to be expected originating at the lower boundary of the frozen substratum, involving frost cycles. The erosive effectiveness of these will however be limited to the equivalent of the pressure cycles. (A double pressure amplitude of 130 m of water head corresponds roughly to a double temperature amplitude of 0.1 deg.)

RELAXATION SELF-OSCILLATIONS AND PROCESSES AT THE BOTTOM OF GLACIERS

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Abstract. In terms of the theory of oscillations, rapid glacier advances (glacier surges) are relaxation self-oscillation, and large glacier advances of the same character dependent on climate are the result of interaction between forced and self-exciting oscillations.

The relation is found between average shear stress and sliding velocity of pure and of moraine-containing ice along the bottom, taking into account the real thermal and kinematic boundary conditions, the different dependence of the ice melting point on hydrostatic pressure

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and on normal component of the stress deviator, and dry friction against the bottom. In the regime of bottom melting, a communicating system of subglacial drainage channels is formed along the borders of distal slopes of bottom irregularities. Variations of effective roughness lead to the forced variations of sliding velocity depending on the surface melting rate.

Relaxation self-oscillations of glaciers are caused by the alternation of "sticking" to the bottom in the phase of restoration and of rapid sliding along the bottom in the phase of relaxation because of the changes in the concentration of moraine material in the bottom layer of ice and of the force of dry friction against the bottom of a glacier.