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Frost heave and sediment entrainment by glaciers

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I examine how the entrainment of sediment by soft-bedded glaciers can be understood as a special case of frost heave dynamics. When basal sediments are present, the thickness of the freeze-on layer is controlled by the balance of forces on the basal ice. The layer thickness is coupled to the heat balance condition by the dependence of the distribution of pore fluid pressures on the rate of melting or freezing. When melting occurs, steady states are possible with a single equilibrium layer thickness (possibly zero) that increases with decreasing melt rate. When freezing takes place, two steady states are possible, the thicker of which is unstable and can lead to the development of sequences of thick (m-scale) alternating clean-ice and sediment-rich ice lenses. Much finer-scale debris bands can be caused by changes to the effective stress. Following such perturbations, the fluid pressure distribution responds rapidly to maintain force equilibrium and this can change the rate or even direction of fluid motion in the lowermost debris layer. The resulting variations in the rate of latent heat release are accommodated by adjustments to the temperature profile over a much longer time scale.