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The phases of frozen ground

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When water is frozen within porous media, interactions between the ice and matrix surfaces produce a diverse array of behavior – including the growth of needle ice at the ground surface, periodic lensing and heave in unconsolidated sediments, the fracture of intact rock, and the incorporation of sediment bands into the basal reaches of glaciers. These phenomena are promoted by the influence of mineral surfaces on the phase behavior of ice, which causes them to be coated by premelted liquid films and results in the generation of substantial heaving pressures. Models aimed at describing these systems are complicated by the need to incorporate physical interactions that operate on the length scale of the films, which are dwarfed by typical grain sizes yet control the macroscopic phenomena. This difficulty has led to a preponderance of ad hoc parameterizations, which have had the unfortunate tendency of obscuring the underlying physics; the driving mechanisms are often mistakenly attributed to more passive effects such as pressure melting and the Gibbs-Thomson effect. We present a model for ice growth in porous media that rigorously incorporates the underlying microphysics within a continuum framework. The model is used to predict how the imposed environmental conditions produce the distinct regimes of behavior that are observed within a given soil.