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Modeling processes in the Arctic from pore- to Darcy scale

Monday 19 May 2025 11:25 (15 minutes)

The Arctic is a complex and vast environment studied by many interdisciplinary teams. In the talk we present our recent results on modeling coupled thermal, hydrological, and mechanical processes in porous soils as well as in the snow portions of the cryosphere. While many models exist for these processes in other contexts, the special features of the Arctic including the subfreezing temperatures, substantial influence of the atmospheric controls, and paucity of data make the modeling from first principles quite valuable, since any model results are hard to verify.

In the talk we present our recent modeling results from first principles at the pore-scale up to the Darcy scale of these coupled processes in the Arctic.

In particular, we account for the change of constitutive properties associated with the freezing/thawing phase transformation in nano- to micro- to meso- and to macro-pores, which result in the liquid water fraction being a continuous rather than a discrete graph known from the Stefan problem. The theoretical and computational derivations we pursue for the upscaling from pore- to the Darcy scale turn out to produce upscaled constitutive properties close to the empirical relationships including the well known Soil Freezing Curve.

Furthermore, the flexibility of working with both of the two scales from the first principles helps to unify the thermal model for soils with the thermal conduction model for the snow, and makes it easy to couple these together. We are also able to account for the flow and deformation coupled to the thermal processes, and to calculate the Darcy scale properties such as the permeabilities depending on the presence of ice at the pore-scale.

This is joint research with Lisa Bigler, Naren Vohra, Zachary Hilliard, Praveeni Mathangadeera, Madison Phelps, and with other students and collaborators to be named in the talk.

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References

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