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Role, Challenges, and Opportunities in Multi-scale Laboratory Experimentation

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Fundamental to the distribution of water and effects on its quality are the processes of energy, mass, and momentum transfer in hydrologic systems. I will introduce a class of problems that offers special challenges when these processes occur either across physical interfaces or through transition zones with embedded interfaces. Some of the challenges are a result of hard to define interface topologies, abrupt transition of phase properties, contrasting phase flow and energy dynamics, difficult to characterize simultaneously occurring but different types of transfer processes, and modeling complexities. The data to study these processes cannot always be obtained from controlled field experiments where many factors contribute to the uncertainty of measurements and parameter estimates. The primary thesis of this talk is that laboratory experimentation at multiple test scales will continue to play an important and a useful role in hydrology and will provide new opportunities to improve fundamental process understanding. This knowledge will lead to increased accuracy of predictions and improved upscaling methods. However, performing such experiments pose many challenges such as acquisition of data at different observational scales and close to interfaces, capturing critical features of geologic heterogeneity, mimicking field specific pressure and temperature dependent phase interaction parameters under ambient laboratory conditions, and simulating climate drivers, among others. Through examples in multiphase systems and land/atmospheric interactions, I will show how to address some of these challenges through the design and implementation of theory-driven experiments.