UPSCALING OF CONSTITUTIVE RELATIONS IN UNSATURATED HETEROGENOUS POROUS MEDIA

H.H. Liu and G.S. Bodvarsson
Contact: H.H. Liu, 510/486-6452, hhliu@lbl.gov

RESEARCH OBJECTIVES

When numerical model are used for modeling field scale flow and transport processes in the subsurface, the problem of "upscaling" arises. Typical scales, corresponding to spatial resolutions of subsurface heterogeneity in numerical models, are generally much larger than the measurement scale of the parameters and physical processes involved. The upscaling problems is, then, one of assigning parameters to gridblock scale based on parameter values measured on small scales. The focus of this study is to develop an approach to determine large-scale (upscaled) constitutive relations (relationships among relative permeability, capillary pressure and saturation) from small-scale measurements for porous media for a range of air entry values that are typical for the tuff matrix in the unsaturated zone of Yucca Mountain.

APPROACH

For porous media with large air entry values, capillary forces play a key role in determining spatial water distribution at large-scales. Therefore, a relatively uniform capillary pressure approximately exists even for a large gridblock scale under steady state flow conditions. Based on these reasoning, we developed formulations that relate upscaled constitutive relations to ones measured at core-scale. Numerical experiments with stochastically generated heterogeneous porous media were used to evaluate the upscaling formulations.

ACCOMPLISHMENTS

Formulations for upscaling constitutive relations were developed for heterogeneous porous media with large air entry value. A typical example of this kind of porous media is the tuff matrix in the unsaturated zone of Yucca Mountain. The validity of these formulations is strongly supported by the numerical experiment results.

SIGNIFICANCE OF FINDINGS

Upscaling is always needed for field scale modeling studies. Although considerable progress has been made in upscaling flow parameters (such as permeability) describing saturated flow, our knowledge of upscaling unsaturated flow parameters is very incomplete. This work represents the first effort to rigorously determine large-scale constitutive relations from small-scale measurements for porous media with high air entry values. The long-term objective in this area is to develop upscaling formulations (approaches) of constitutive relations for more general porous media.

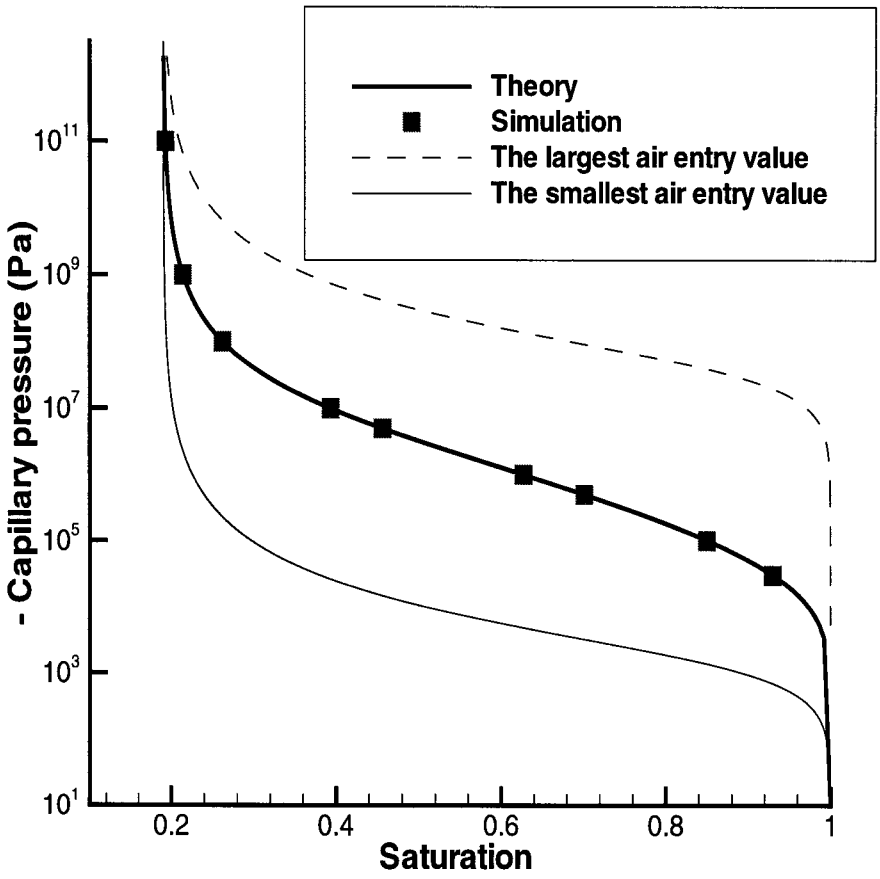
RELATED PUBLICATIONS

Liu, H.H. and G.S. Bodvarsson, Upscaling of constitutive relations in unsaturated heterogenous porous media with large air entry values, Water Resources Research, in review.

ACKNOWLEDGEMENTS

This work was supported by the Director, Office of Civilian Radioactive WasteManagement, U.S. Department of Energy, through Memorandum Purchase Order EA9013MC5X between Bechtel SAIC Company, LLC and the Ernest Orlando Lawrence Berkeley National Laboratory (Berkeley Lab). The support is provided to Berkeley Lab through the U.S. Department of Energy Contract No. DE-AC03-76SF00098.

(Figure 1. Comparison between upscaled water retention curves and the simulated data points. Local water retention curves with the largest and smallest air entry values are also shown to demonstrate the spatial variability within the porous medium used in numerical experiments)


Theory
Simulation
The largest air entry value
The smallest air entry value
- Capillary pressure (Pa)
10^{11}
10^{9}
10^{7}
10^{5}
10^{3}
10^{1}
0.2
0.4
0.6
0.8
1
Saturation