Subsurface Flow and Transport Modeling: Upscaling, Inversion, and Model Complexity

Ye Zhang
Department of Geology & Geophysics
University of Wyoming

Bio: Ye Zhang received her B.S. degree in Hydrogeology from Nanjing University, People's Republic of China; her M.S. degree in Hydrogeology from the University of Minnesota, with a M.S. Minor in Civil Engineering; and her Ph.D. in Hydrogeology from Indiana University, with a Ph.D. Minor in Scientific Computing. She is currently an Associate Professor in the Department of Geology and Geophysics, University of Wyoming. Her research interests include geologic modeling/geostatistics, upscaling, inversion, and uncertainty analysis for subsurface applications. Recent interest includes drilling, instrumentation, and modeling of interconnected surface and groundwater systems in mountain headwater regions.

Abstract: Numerical modeling is used to evaluate a variety of subsurface flow and transport phenomena, although significant uncertainty in model parameters, processes, and boundary conditions exists. This talk will first discuss parameter uncertainty whereas, due to data scarcity or computation limitation, simplified subsurface conceptual models are constructed without resolving smaller scale parameter variability. However, higher resolution models often incur greater characterization costs. This raises the questions of what kind of model should be built for different objectives, and at what resolution? For a set of hierarchically coarsened conceptual models, a connectivity-based permeability and dispersivity upscaling technique is developed to calculate equivalent parameters, thus bulk flow and transport arising out of the underlying heterogeneity can be captured. In modeling geologic carbon sequestration, these models are compared within their full parameter space, yielding insights into optimal heterogeneity resolution for meeting different prediction goals under uncertainty. To address boundary condition uncertainty, a new and computationally efficient subsurface fluid flow inverse theory is developed for confined and unconfined aquifers to simultaneously estimate parameters (e.g., permeabilities and storativities), state variables, and boundary conditions. Uncertainty in subsurface static data can be accounted for, while permeability structure can also be identified. The theory addresses model "structure errors", either simplifying due to limited data or complexifying due to process uncertainty, by estimating equivalent parameters, thus providing a means of constructing optimally coarsened models if detailed measurements needed for upscaling do not exist. The theory has been successfully extended to inverting transient and unsaturated flows. Recently, it has been extended to address issues in contaminant source identification when solute transport in the subsurface suffers both unknown initial and boundary conditions.