Applications of Pneumatic Inverse Model to Estimate Hydrogeologic Properties in Heterogeneous Unsaturated Formations

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Abstract

The distributions of permeability and porosity are key factors that control airflow and gas phase transport in unsaturated formations. To understand detail behaviors of airflow and transport in such formations, a general approach that has been widely applied to laboratories and fields is through characterization process. As was generally recognized, this approach relies on accurate measurements in laboratories or at sites and, more importantly, an adequate tool to interpret those measurements from experiments. This study presents a pneumatic tomography model to estimate the distributions of permeability (K) and porosity (S) with higher resolution in unsaturated formations. Based on the concept of sequential successive linear estimator (SSLE), the developed model accounts for compressibility and density of air and estimates the hydrgeologic parameters using air pressure measurements from sequential cross-hole pneumatic pumping or injection tests. Four synthetic examples were used to validate and test our tomographic model in estimating the distributions of permeability and porosity in unsaturated formations. Results of the numerical experiments are promising. Our pneumatic tomography model can exactly reconstruct the property (i.e., permeability and porosity) fields if the well-defined conditions are met. With relatively small number of available measurements, the proposed tomography model can accurately capture the patterns and the magnitude of estimated properties in unsaturated formations. Two application examples showed that the proposed model can map the fracture connectivity using relatively small number of pressure measurements and estimate K and S in shallow aquifer using spatial variations of atmospheric pressure.