Time to Change the Way we Collect and Analyze Data for Characterizing the Subsurface

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Fluid particles migrate through geologic media of multi-scale heterogeneity with energies varying temporally and spatially at multiple scales. Our inabilities to develop mathematical models for such complex systems, and our failures to characterize such systems in detail have forced us to rely on continuum and homogenization approaches, and to adopt diffusion and dispersion concepts (i.e., artifacts of our ignorance). For the same reasons, porous continuum approach and dual porosity/mass transfer concept for flow through fractured rocks have been developed. While successes of these approaches and concepts have been reported for predicting general behaviors, failures are common as the scale of our interest becomes finer. Nevertheless, practicality and principle of parsimony are often used as justifications for these simplified concepts and approaches.

Recent advances in sensor, computing, and information technology as well as forward and inverse modeling methodology have paved the way to the new era of subsurface characterization. In this presentation, I explain why tomographic surveys (fusion of the same type of information) and joint inversion (fusion of different types of information) can make inverse problems better posed, and can minimize the phenomenological nature of parameter estimates. Additionally, effective inverse (data fusion) algorithms are discussed and successes of their recent applications to hydraulic, electric, tracer tomography for imaging porous and fractured geologic media based on numerical, lab, and field experiments are presented. Subsequently, numerical examples illustrating the feasibility of applications of the tomographic survey concept to stream-aquifer systems at the basin scale are demonstrated and new sampling and characterization strategies are suggested for hydrologic observatory. Finally, we advocate that monitoring, characterizing, and predicting the subsurface processes at high resolution over basin and continental scales should be the goal of the future subsurface science research.