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Nonlinear Dynamic Processes as a Source of Uncertainty for Flow Simulations through Partially-Saturated Fractured-Porous Media

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The concept of nonlinear dynamics and chaos can be used to provide an alternative explanation for seemingly erratic temporal and spatial behavior and the irreducible uncertainty of variables characterizing flow and transport through unsaturated fractured-porous media. The apparent "randomness" of the flow field does not prohibit the system's "determinism" and, in fact, can be described by deterministic differential or difference-differential equations. Nonlinear physical processes within partially saturated fractured-porous media (such as chaotic advection, diffusion, mixing, sensitivity to initial conditions, and feedback phenomena) result from the interplay of intrafracture film flow along fracture surfaces, coalescence, divergence, and mixing of multiple flow paths along fracture surfaces, and intrafracture water dripping. Because direct measurements of variables characterizing a variety of flow and transport processes under field conditions are not technically feasible, only a cumulative effect of these processes can be characterized. The lack of specific measurements leads to a limited knowledge about the flow processes needed for constructing particular models to describe the geometry and physics of chaotic flow processes. Therefore, it would be difficult, if not impossible, to distinguish between the two components of the total uncertainty—epistemic and aleatoric uncertainties. Using the time-domain and phase-space presentation of time-series data for the infiltration and outflow rates, capillary pressure, and dripping-water frequency obtained from several infiltration tests, the author will present the results of the statistical evaluation (using the moments analysis and a concept of information entropy) of temporal and spatial uncertainty for variables characterizing the unsaturated flow. This work was supported by the U.S. Dept. of Energy under Contract No. DE-AC02-05CH11231.