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How effective are effective parameters?

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Presence of spatial heterogeneities and temporal variations at various scales are perhaps the greatest source of difficulty in our ability to model flow and transport in porous media. We are often not able to include small-scale heterogeneities and variations in our models. Instead, their effects are accounted for by introducing effective processes and/or effective parameters. Some well-known examples of effective processes (and corresponding parameters) are hydrodynamic dispersion (and dispersivity), kinetic mass transfer (and rate constants). The upscaled equations often contain some dynamic or non-equilibrium effects that are not present in the small-scale process description. Thus, the correct upscaling procedure is to upscale small-scale governing equations, which leads to (new) effective processes, and then determine the new (effective) parameters in the upscaled equations. Too often, however, the governing equations are not upscaled but only their parameters are "upscaled." These are then called effective parameters. For example, for a heterogeneous medium, Darcy's law is assumed to hold at all scales and only permeability is "upscaled." Or, adsorption is assumed to obey an equilibrium isotherm and only the adsorption coefficient is upscaled. We believe that such an upscaling procedure is potentially deficient and results in burying upscaled dynamic (or non-equilibrium) effects in the so-called effective parameters. In this presentation, we discuss the fact that upscaling almost always results in the introduction of (new) non-equilibrium terms in the upscaled equations. We illustrate these concepts by examining capillary pressure-saturation relationship for heterogeneous porous media and presents results of laboratory and modeling work,

which show that a non-equilibrium term must be introduced in upscaled capillary pressure-saturation relationships.