Research Interests
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Standard porous medium model

\[
\frac{\partial}{\partial t} (\epsilon^\alpha \rho^\alpha \omega^{i\alpha}) = -\nabla \cdot (j^{i\alpha} + \epsilon^\alpha \rho^\alpha \omega^{i\alpha} \mathbf{v}^\alpha) + \mathcal{I}^{i\alpha} + \mathcal{R}^{i\alpha} + \mathcal{S}^{i\alpha}
\]

\[
\frac{\partial}{\partial t} (\epsilon^\alpha \rho^\alpha) = -\nabla \cdot (\epsilon^\alpha \rho^\alpha \mathbf{v}^\alpha) + \mathcal{I}^\alpha + \mathcal{S}^\alpha
\]

Standard closure relations, Darcy’s Law:

\[
\mathbf{q}^\alpha = \epsilon^\alpha \mathbf{v}^\alpha = -\frac{k^\alpha}{\mu^\alpha} \cdot (\nabla p^\alpha + \rho^\alpha g \nabla z)
\]

Pressure-Saturation Relation:

\[S^\alpha = f \left( p^\beta(t) \right), \text{ for } \beta = 1, \ldots, n_f\]

Saturation-Conductivity Relation:

\[k^{r\alpha} = f \left( S^\beta(t) \right), \text{ for } \beta = 1, \ldots, n_f\]
Example Areas of Interest

1. Deriving alternative models to the standard model that respond to some of the open issues
   
   (a) lack of thermodynamic constraints

   (b) hysteretic closure relations

   (c) no specific account for interfacial areas

   (d) assumptions of local physical and chemical equilibrium

   (e) lack of direct connections between fundamental microscale notions and macroscale equations
2. Development and application of pore-scale models for a variety of uses

(a) closure relations for standard models: capillary pressure, saturation, permeability; viscous coupling; tortuosity; dispersion, dissolution

(b) rules for network models

(c) prediction and correlation of physical parameters

(d) closure relations for evolving models, such as pressure-saturation-interfacial areas, dynamic $p-S-k$ relations, etc
3. Development of improved macroscale models for interphase mass transfer

(a) NAPL dissolution and fingering models, upscaling

(b) solute sorption from fluid phase to solid particles, including multi-scale approaches

(c) comparison of evolving models to experimental data sets

4. Numerical methods for solving multiphase continuum models

(a) solution algorithms, e.g., split-operator methods

(b) adaptive, higher-order temporal integration
(c) locally, mass conserving discretization schemes, such as mixed finite element methods and discontinuous Galerkin methods

(d) spatially and temporally adaptive methods

(e) efficient solution of large, sparse nonlinear systems of algebraic equations

(f) optimization methods for optimal design

5. Computational science issues

(a) object-oriented methods

(b) problem solving environments

(c) parallel implementations of algorithms
6. Remediation technology development

(a) dense brine behavior in heterogeneous systems

(b) complex mixture behavior

(c) development of suitable simulator

(d) optimal design

7. Stochastic aspects

(a) effects of heterogeneity on transport phenomena

(b) stochastic computation

(c) representation of heterogeneity