Simulating fluid flow in fractured reservoirs with The Matlab Reservoir Toolbox (MRST)

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IRIS

photo by Chuck DeMets

Agenda

- Modeling philosophy
- Equations and discretizations
- Modeling concepts for fractures
- Numerical examples

Mathematical models

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- Darcy's law (unit viscosity):

$$\boldsymbol{v} = -\mathbf{K}\nabla p$$

- Conservation of mass (single phase, incompressible) →

$$\nabla \cdot \boldsymbol{v} = q$$

- Pressure equation:

$$-\nabla \cdot (\mathbf{K}\nabla p) = q$$

- Tracer transport:

$$\phi \frac{\partial c}{\partial t} + \nabla \cdot (c\boldsymbol{v}) = q_t$$

Finite-volume method

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- Integral formulation

$$\int_{\partial\Omega_i} (\boldsymbol{v}\cdot\boldsymbol{n})\mathrm{d}S = \int_{\Omega_i} q\ \mathrm{d}\Omega$$

- Flux approximation

$$\int_S (\boldsymbol{v}\cdot\boldsymbol{n})\mathrm{d}S \approx \sum_{k=1}^{\nu} t_k p_k$$

- Linear system

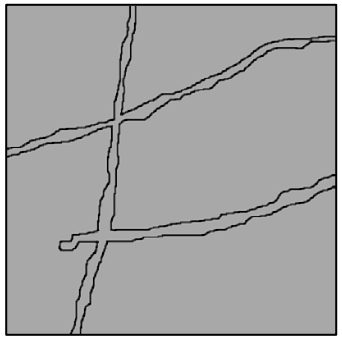
$$\boldsymbol{A}\boldsymbol{p} = \boldsymbol{q}$$

Modeling concepts

Large- and small-scale fractures

Upscaling

Discrete fracture model + continuum model

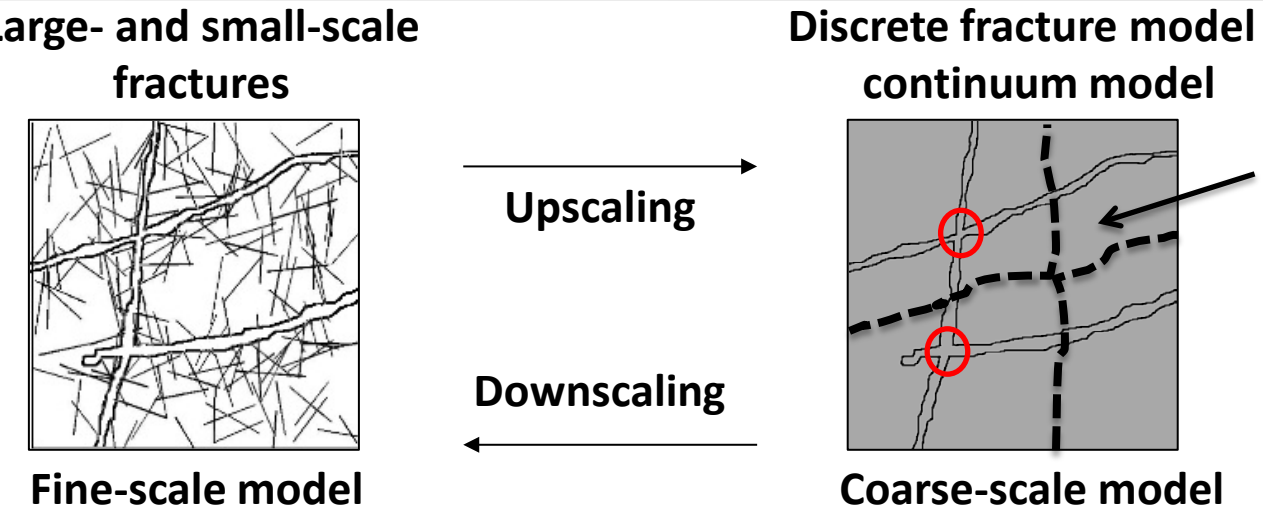


- Hierarchical modeling:
  - Large-scale fractures: explicitly
  - Small-scale fractures: effective permeability (anisotropic)
- Consistent and robust discretization of flow in fractured reservoirs
- incompTPFA_DFM / incompMPFA_DFM

Object:

- But…..
  - What if the conditions for upscaling is not valid? (no scale – separation etc.)
  - Only coarse transport
- We want a method that is:
  1. Comparable with upscaling when the conditions for upscaling apply
  2. Otherwise, comparable with standard fine-scale solvers
  3. Capable of fine-scale transport

Modeling concepts



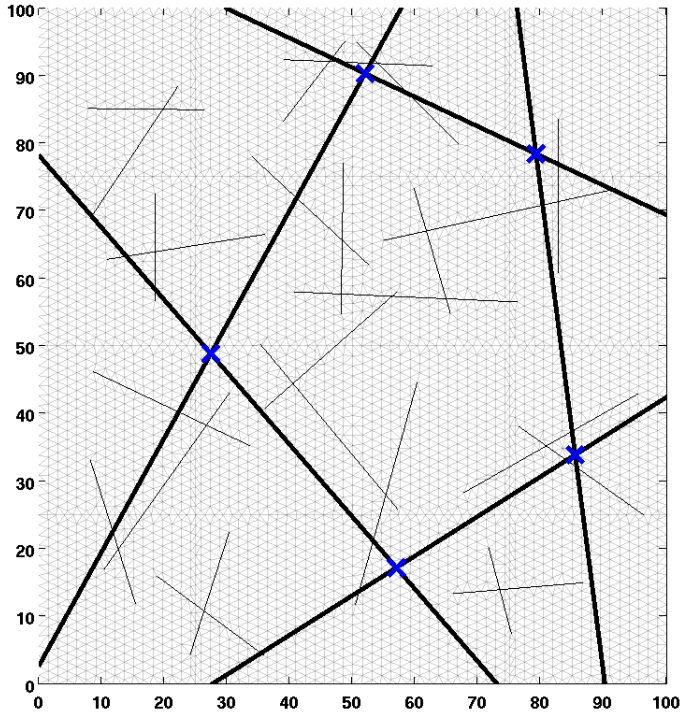
- MsFVM: Multiscale finite volume method (Jenny 2003)
  - Coarse grids
  - Post-processing
  - Direct method / Multiscale method
  - Inexact solver / Preconditioner in GMRES
- solveMSFV_TPFA_Incomp_DFM

Example setup

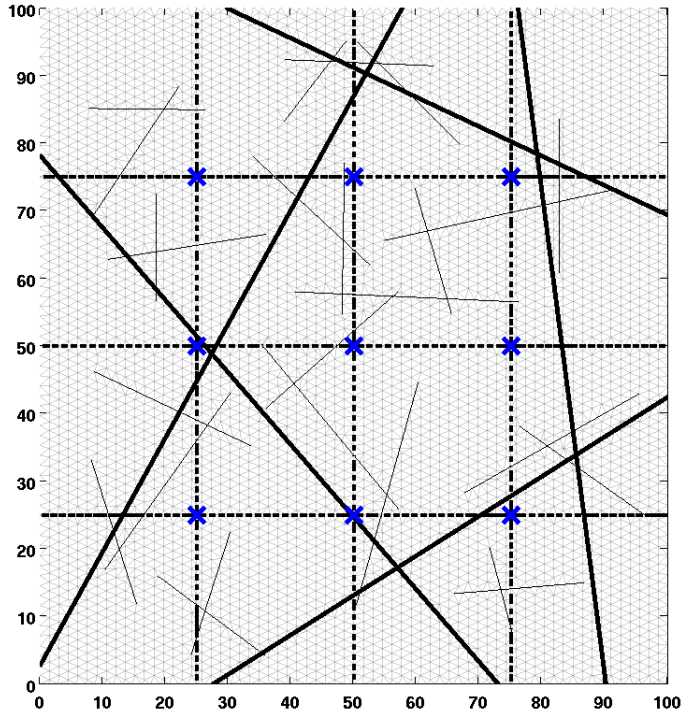
- Aperture large-scale fractures: 1mm
- Aperture small-scale fractures: 0.5mm
- Fracture permeability = $\frac{\text{aperture}^2}{12}$
- Fracture porosity: 1
- Matrix permeability: 1mDarcy
- Matrix porosity: 0.01

Case 1

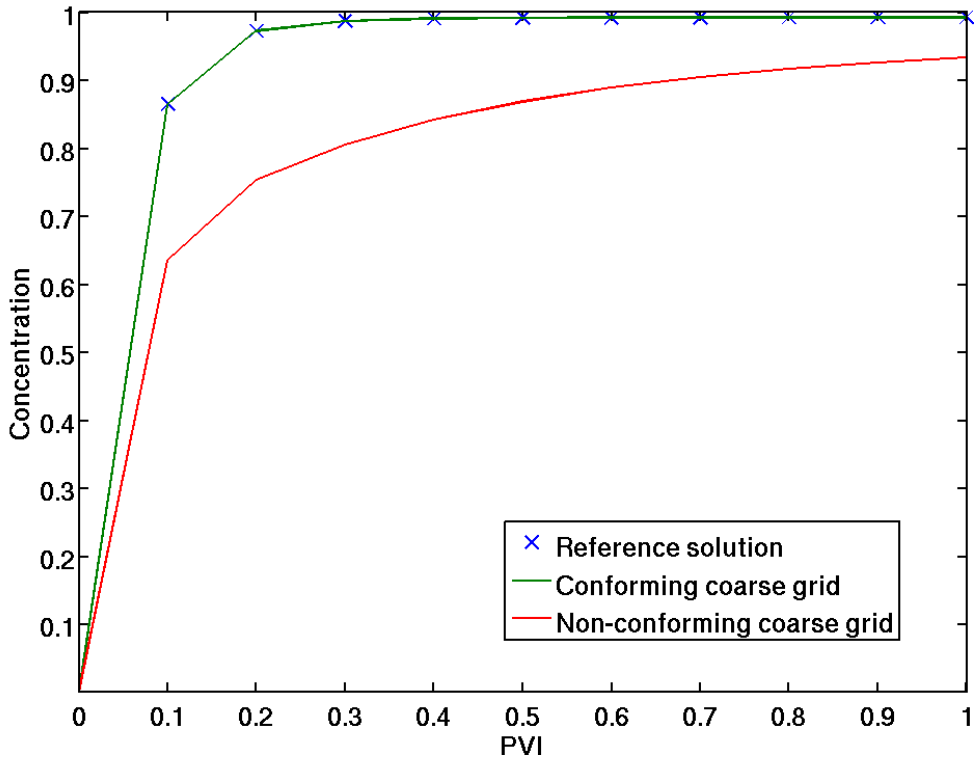
- Conforming coarse grid



- Non-conforming coarse grid



Compare as multiscale method



Compare as multiscale method

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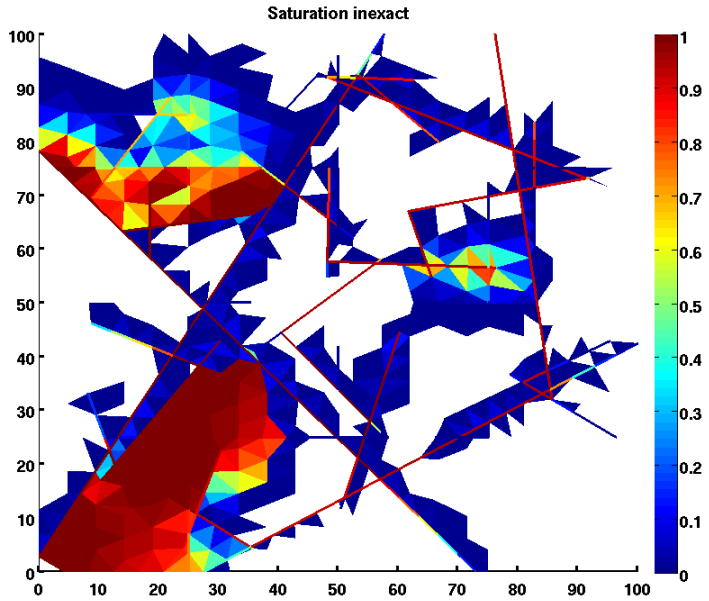
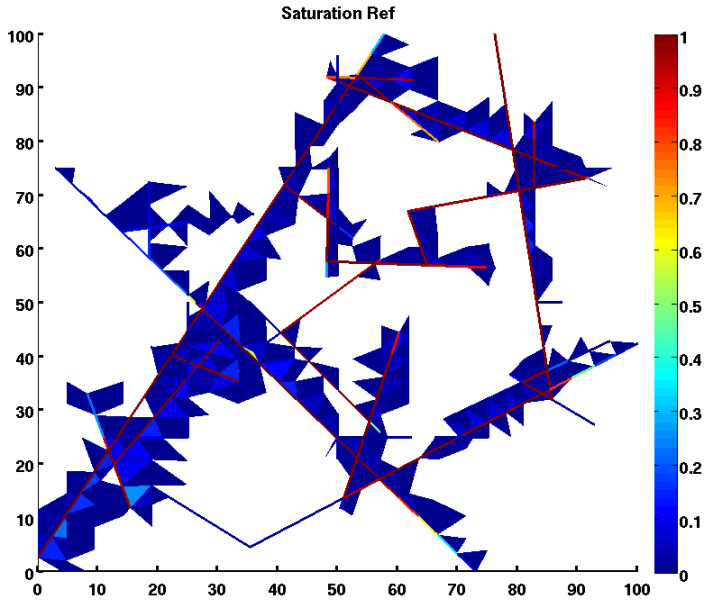
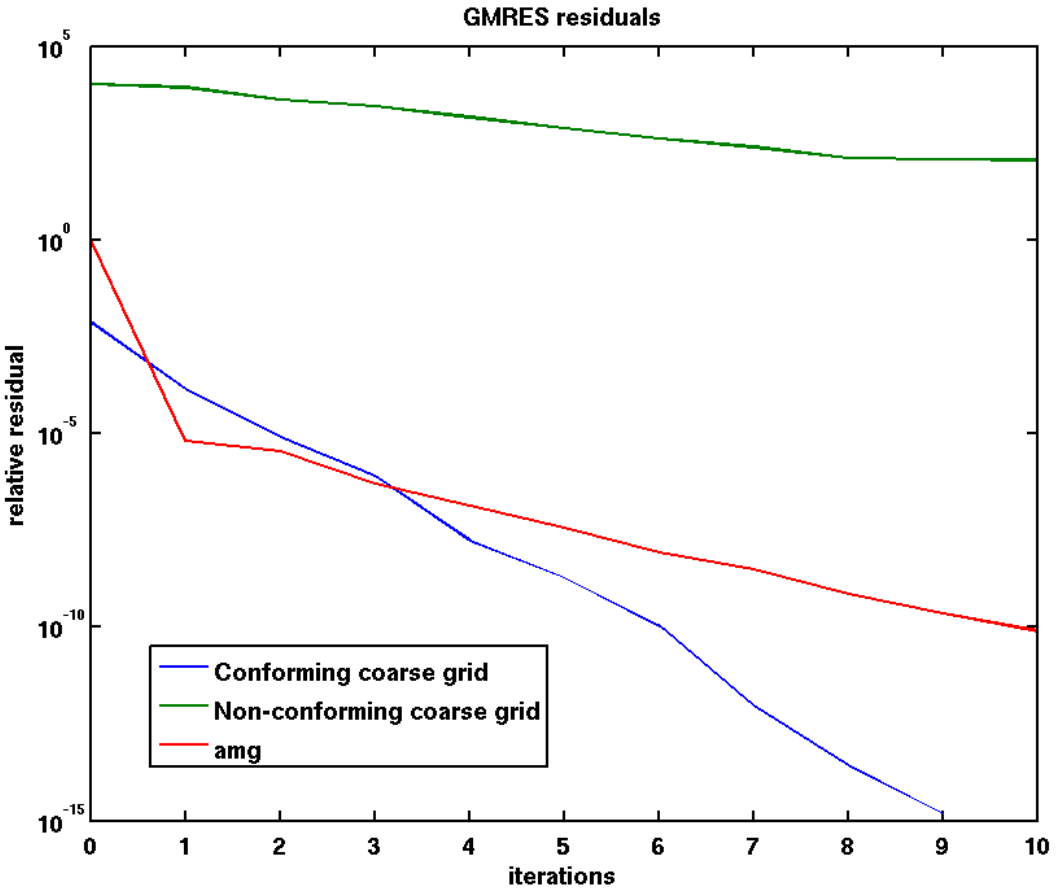
- Multiscale solution



- Reference solution



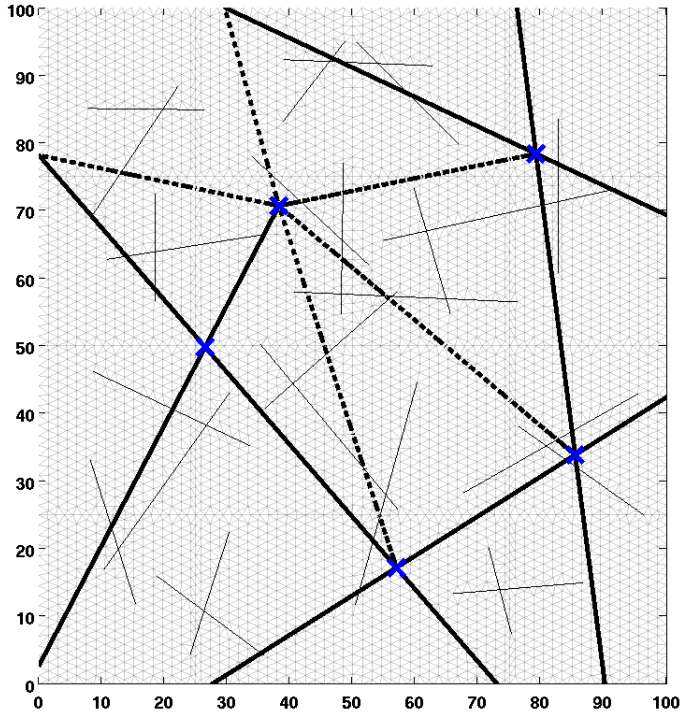
Compare as preconditioner



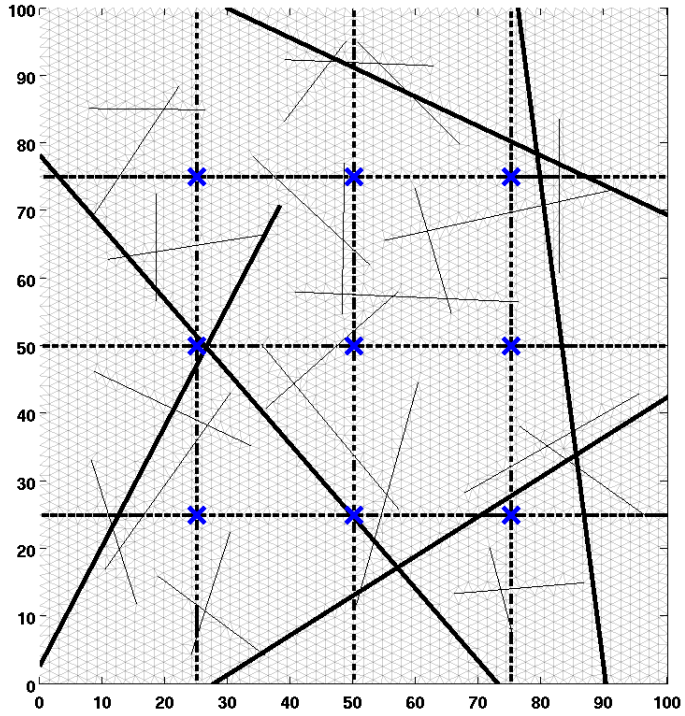
AMG: Y. Notay 2010

Case 2

- Conforming coarse grid

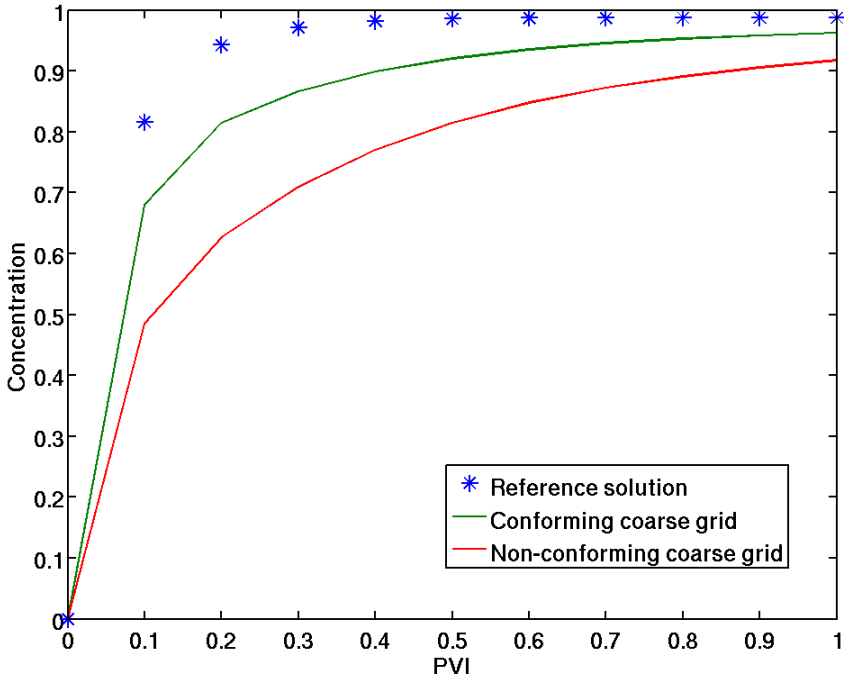


- Non-conforming coarse grid

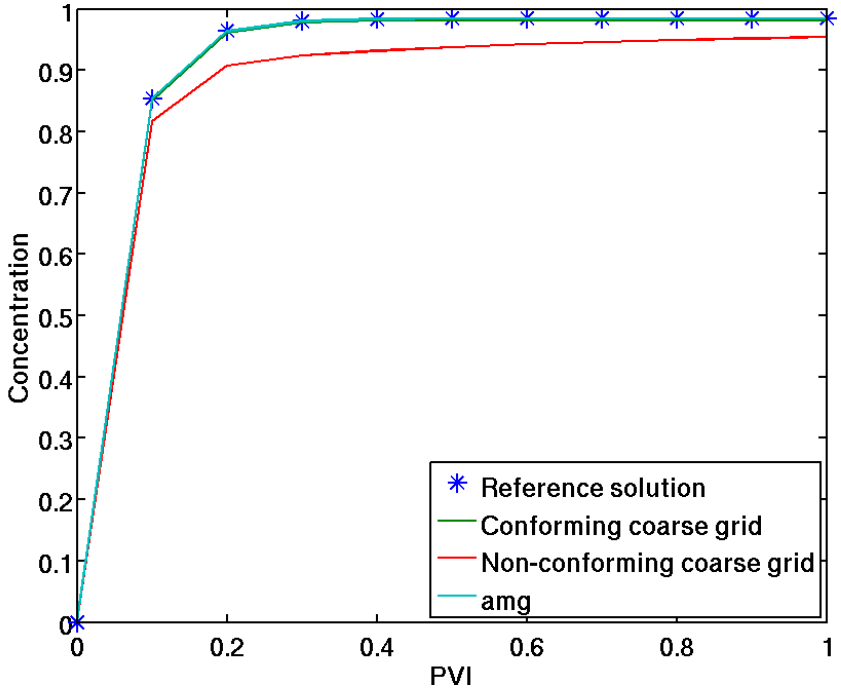


Case 2

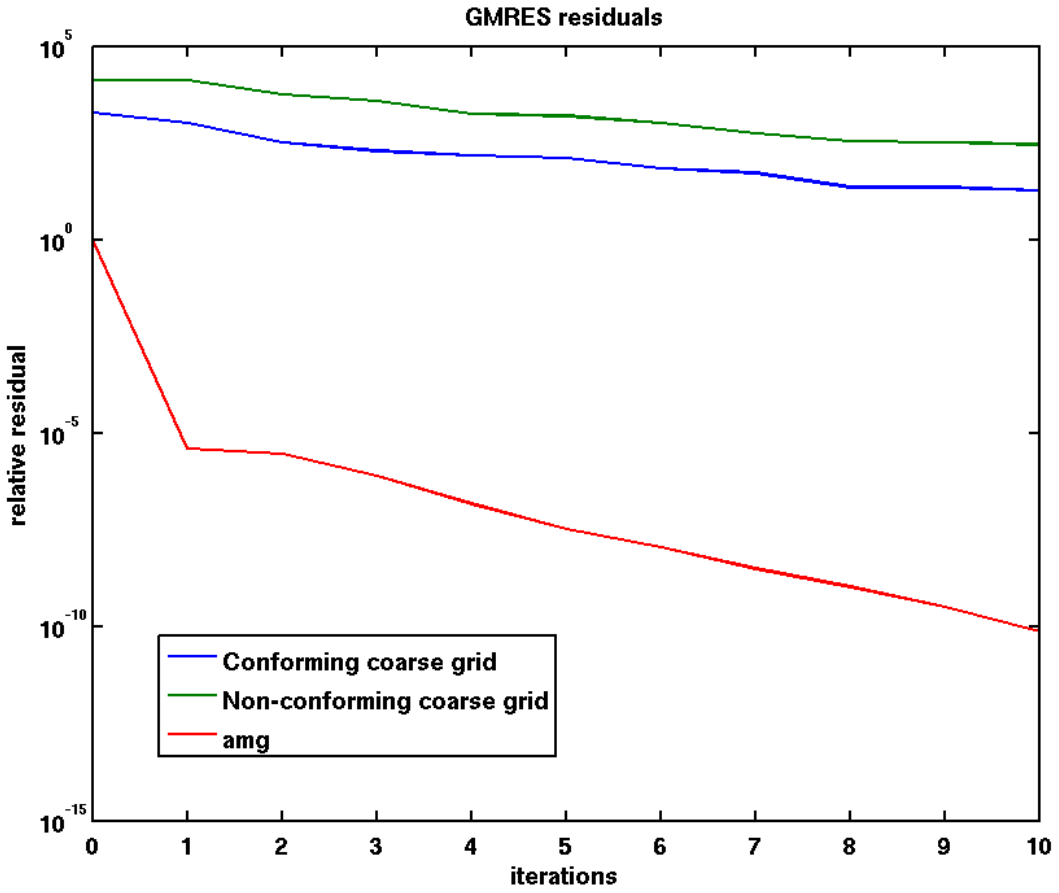
- Direct method



- 10 GMRES iterations



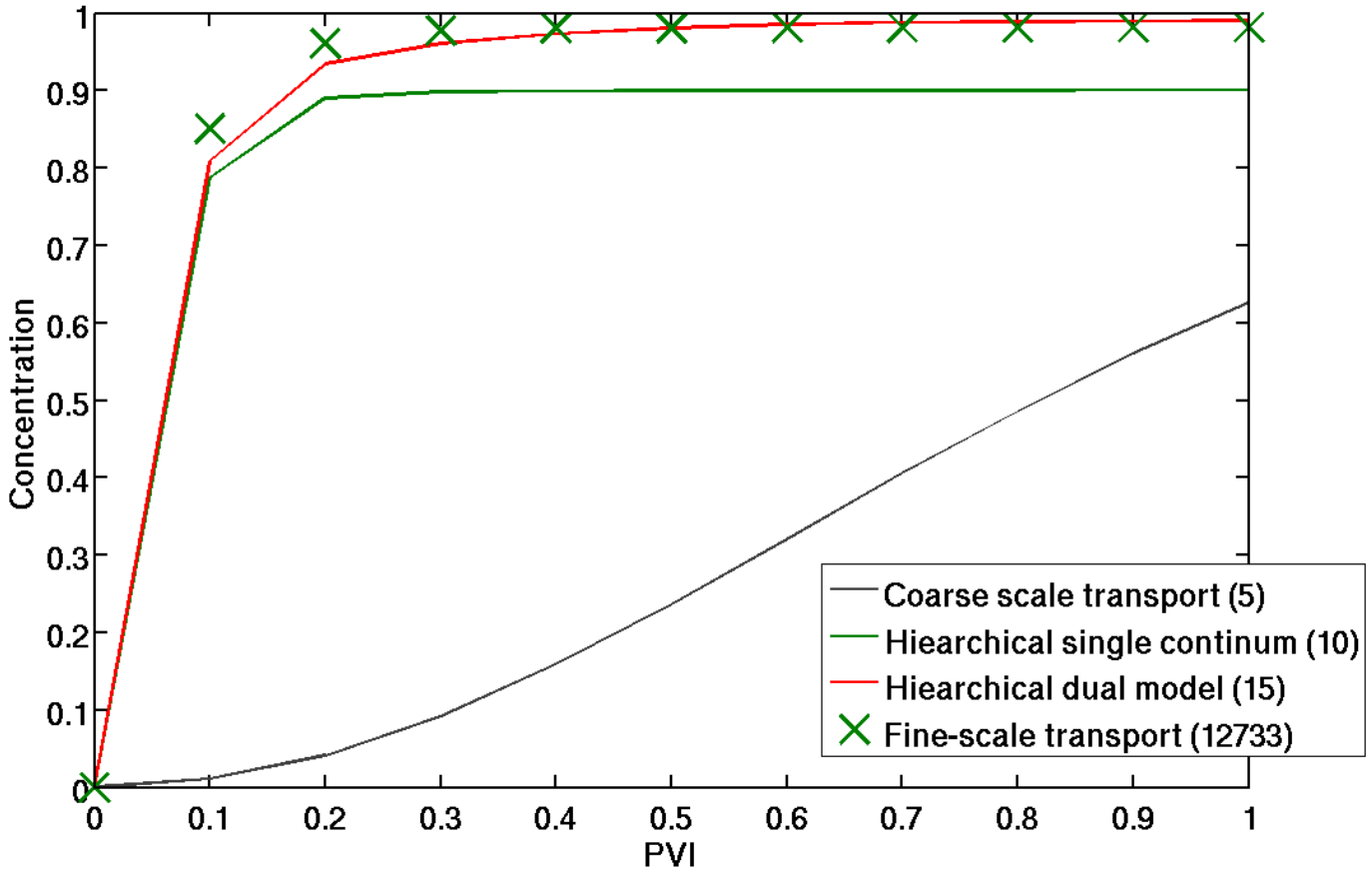
Compare as preconditioners



Transport upscaling

- Coarse transport
- Hierarchical models
  - Large-scale fractures explicit
- Dual models
  - Small-scale fractures into a fracture continuum

Transport models



After thoughts

- Pressure equation:
  - Linking uncertainty and stopping criteria for the linear solvers
- Transport
  - Flow based upscaling
  - aMINC (automatic Multiple INteracting Continua)