Contribution ID: **558** Type: **Oral 20 Minutes**

Multiscale Computation of Pore-Scale Fluid Dynamics

Thursday, 17 May 2018 11:23 (15 minutes)

Understanding the dynamics of fluid flow and transport in porous media is important in several subsurface applications including geologic CO2 storage, hydrocarbon recovery, geothermal energy, and groundwater hydrology. In order to control and optimize said dynamics, it is imperative that these processes be considered at the pore (or micro) scale. Pore-scale models provide a useful means of approaching such problems. However, current direct numerical simulation (DNS) methods can be prohibitively expensive, even though they produce the highest fidelity predictions. On the other hand, certain surrogate models (e.g., pore-network models) are considerably less expensive and can be used to approximate the fluid flow physics in porous media. However, current surrogate models often lack the ability to control/shrink their prediction errors. In other words, the concept of "convergence to a solution"is absent. In this work, we present a new computational framework for simulating fluid flow dynamics at the pore scale. We demonstrate that through a combination of multiscale, multiresolution, and domain decomposition concepts the Navier-Stokes equations can be solved very efficiently on porous materials with structures of arbitrary complexity. Moreover, the framework provides the ability to converge, in a step-by-step fashion, to the full DNS solution through successive iterations. This renders the approach flexible for a variety of applications in/outside geosciences, which pose different tolerances for error.

References

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Session Classification: Parallel 10-G

Track Classification: GS 2: Computational challenges in porous media simulation