Multiscale Discretizations for Flow, Transport and Mechanics in Porous Media

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A fundamental difficulty in understanding and predicting large-scale fluid movements in porous media is that these movements depend upon phenomena occuring on small scales in space and/or time. The differences in scale can be staggering. Aquifers and reservoirs extend for thousands of meters, while their transport properties can vary across centimeters, reflecting the depositional and diagenetic processes that formed the rocks. In turn, transport properties depend on the distribution, correlation and connectivity of micron sized geometric features such as pore throats, and on molecular chemical reactions. Seepage and even pumped velocities can be extremely small compared to the rates of phase changes and chemical reactions. The coupling of flow simulation with mechanical deformations is also important in addressing the response of reservoirs located in structurally weak geologic formations.

We will focus on the mortar mixed finite element method (MMFE) which was first introduced by Arbogast, Cowsar, Wheeler, and Yotov for single phase. The MMFE method is quite general in that it allows for non-matching interfaces and the coupling of different physical processes in a single simulation. This is achieved by decomposing the physical domain into a series of subdomains (blocks) and using independently constructed numerical grids and possibly different discretization techniques in each block. Physically meaningful matching conditions are imposed on block interfaces in a numerically stable and accurate way using mortar finite element spaces. The mortar approach can be viewed as a subgrid or two scale approach. Moreover, as shown in recent work by Girault, Pencheva, Sun, Yotov, and Wheeler the use of mortars allows one to couple MFE and discontinuous Galerkin approximations in adjacent subdomains. In this presentation we will discuss theoretical a priori and a posteriori results and computational results will be presented.