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A hierarchical block structured space-time spectral element method for simulating complex multiphase flows

A new parallelized hierarchical space-time spectral element method has been developed for simulating multiphase compressible or incompressible flows in which the bulk regions of one or more of the fluids can be complex. Such flows occur in the study of ocean currents, atomization and spray in combustion engines, and bubbly flows. In our previous work in simulating multiphase flows on a hierarchical block structured adaptive grid (Jemison et al 2014), the level of efficiency of dynamic adaptive mesh refinement had to be decreased because the numerical solution on coarse levels was overly damped, resulting in incorrect feedback on multiphase interface(s), or retarding naturally occurring nonlinear flow phenomena. We shall present original work in which the solution in spectral elements spanning a single material is represented with space-time spectral accuracy (Pei, Sussman, Hussaini JSC, 2018). The discretization in multimaterial (>1 material) elements is the same as in our previous work. Our present hierarchical adaptive mesh strategy is to prescribe the highest order spectral elements on the coarse adaptive levels, and progressively reduce the order on finer levels. A relatively easy to implement multigrid preconditioned BiCGSTAB (MGPBiCG) algorithm has been developed for the variable density projection equation on our new hierarchical adaptive spectral element grid. The efficiency of the MGPBiCG solver is comparable to that of the lower order MGPCG counterpart.