

Parallel-in-time-and-space simulation for a class of models with non-local operators

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Anomalous sub-diffusion processes governed by non-local operators have been employed to model complex single- and multi-phase fluid flow in unconventional reservoirs, particularly to understand the long-time behavior of key quantities of interest. These processes, which require long-time simulation, are described using a non-local-in-time fractional derivative form of Darcy's law coupled with a conservation of mass equation. Standard time-stepping discretizations of these models lead to computational bottlenecks during long simulations. Additionally, memory limitations on each node (of a HPC cluster) constrain the ability to resolve fine-scale spatial structures. To address these challenges, we present a hybrid parallel-in-time and parallel-in-space mixed finite element discretization framework. This approach enables efficient long-time simulations of first-order models by alleviating the time-stepping bottleneck and, within node memory constraints, supports high-resolution approximations of the underlying continuous models.