Petascale Algorithms for Transport Simulation

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Realization of peta- and exascale simulation science will require new developments in discretizations and linear solvers for partial differential equations. In many science areas the quest for increased computational resources is driven by a need to span a broader range of scales, that is, to capture the interaction of small scales with the large. In transport problems such as electromagnetics and fluid mechanics, this increased range implies a need to propagate small scale features over long times and distances, which is most effectively accomplished using high-order methods, as established by Kreiss and Oliger in the 70s. Here, we present recent advances in spectral element methods designed for the petascale architectures that are soon to be deployed by several national agencies, including the DOE and NSF. In particular, we address scalable coarse-grid solvers in the context of multigrid solutions of the pressure system governing large-scale fluid dynamics simulations on $>$ 64,000 processors. Application areas include the study of magnetorotational turbulence in accretion disk models, thermal hydraulics of advanced recycling reactors, wakefield computations in accelerators, and transition in vascular flows.

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