Equation Free Projective Integration, A Multiscale Modeling Technique: 1D Scaling Results and Application to Magnetic Reconnection

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We examine a novel simulation scheme called "equation free projective integration"[1] which has the potential to allow global simulations which still include microscale physics, a necessary ingredient in order to model multiscale problems. Such codes could be used to examine the global effects of reconnection and turbulence in the Earth's magnetosphere, the solar corona, the heliosphere, as well as in laboratory Tokamaks. Using this method to simulate the propagation and steepening of a 1D ion acoustic wave, we have already achieved excellent agreement between full particle codes and equation free with a factor of 20 speed-up. This speedup appears to scale linearly with system size, so large scale 2D and 3D simulations using this method will show a speedup of 100 or more. In this method of simulation, the global plasma variables stepped forward in time are not time-integrated directly using dynamical differential equations, hence the name "equation free." Instead, these variables are represented on a microgrid using a kinetic simulation. This microsimulation is integrated forward long enough to determine the time derivatives of the global plasma variables, which are then used to integrate forward the global variables with much larger timesteps. Results will be presented of the successful application of equation free to 1-D ion acoustic wave steepening with a PIC code serving as the underlying kinetic model. Initial results of this technique applied to magnetic reconnection will also be presented.

1 I. G. Kevrekidis et. al., Equation-free multiscale computation: Enabling microscopic simulators to perform system-level tasks, arXiv:physics/0209043.