Simulations of space weather in Earth’s magnetosphere demonstrate that while ideal magnetohydrodynamics (MHD) adequately models the large majority of the domain, regions of fast magnetic reconnection require fine-scale resolution. Recently Kuznetsova et al. simulated bursty reconnection in Earth’s magnetotail by embedding analytically computed corrections applied to the electric field in reconnection-layer regions [Kuznetsova07]. Appropriate embedding of a kinetic model, which is more generic and accurate, would enable resolution of reconnection-layer physics, including the more complex, 3-dimensional forms of reconnection observed in the dayside region.

We embed a kinetic model implemented using a particle-in-cell (PIC) code within an MHD model implemented with shock-capturing finite-volume code (see [Rossmanith06]). By decomposing the spatial domain into a small PIC region embedded within a large ambient MHD domain we expect to compute PIC-level resolution for the GEM reconnection challenge problem [Birn01] expanded to an effectively infinite domain. In order to smoothly join the two models together, we “stitch” (interlock) them at the boundary of the PIC region using a “sponge” layer, as done in [Sugiyama07] for one dimension. Since we design boundary conditions to minimize spurious reflections at the MHD/PIC interface, we carry out careful studies of 1D wave transmission across the interface.

We ultimately wish to develop an MHD/PIC adaptive multiscale algorithm that dynamically identifies regions where the algorithm should transition between models. Reference [Schumer01] maps out two overlapping regions of parameter space: (1) where PIC is feasible and (2) where MHD is valid, and discusses how to transition state variables from MHD to PIC. We hope to combine their temporal mechanisms for model transition with spatial stitching of these conceptually simple models to support an efficient and broadly applicable algorithm that effectively identifies and accurately resolves regions of fast magnetic reconnection.

References


