Development of the SEL code and its application to the magnetic reconnection problem.

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Abstract

A new massively parallel three-dimensional spectral/(hp) element [1] code (SEL) [2] is being developed at LANL in order to address several key issues in computational plasma physics – such as the presence of multiple length/time scales and high degree of anisotropy in most plasmas of interest. Second-order adaptive implicit Newton-Krylov time advance and quasi-static evolution of the computational grid to remain approximately parallel to the magnetic field (field-alignment) with perpendicular adaptive mesh refinement are the main tools we propose for resolving those issues. Presently, a two-dimensional (2D) version of the code is operational and is being tested with applications to magnetic reconnection and tokamak edge plasma modeling.

Physical evolution equations are formulated in a simple flux-source form, which allows for great flexibility in physical systems to be modeled by the code. The formulation is also independent of any particular logically rectangular coordinate system one chooses to compute on; subject only to the knowledge of the Jacobian of that coordinate system. This is done both in anticipation of the field-alignment algorithm now under development and to greatly simplify an implementation in any given curvilinear coordinate system.

The code has been tested against several numerical and semi-analytical studies of 2D magnetic reconnection in resistive MHD, Hall-MHD, and EMHD regimes [3], extending the published results where possible. In the near future, we will enhance the physical model to include further two-fluid and pressure tensor effects in order to be able to self-consistently model both microscopic (i.e. detailed structure of localized reconnection sites) and macroscopic (i.e. global evolution of a magnetized plasma) processes, whose interaction is crucial to any astrophysical or laboratory plasmas in which fast magnetic reconnection plays a significant role.

[1] G. E. Karniadakis and S. J. Sherwin, *Spectral/hp Element Methods for CFD* (Oxford University Press, New York, 1999).

[2] A. H. Glasser and X. Z. Tang, to appear in Comp. Phys. Comm. (2004).

[3] I. J. D. Craig *et.al.*, Phys Plasmas **10**, 3120 (2003); J. D. Huba, L. I. Rudakov, Phys Plasmas **10**, 3139 (2003); D. Del Sarto *et. al.* Phys. Rev. Lett. **91**, 235001 (2003); Richard Fitzpatrick, Phys Plasmas **11**, 937 (2004).