The SEL Macroscopic Modeling Code

A. H. Glasser and X. Z. Tang
Los Alamos National Laboratory, Los Alamos, NM 87545

SEL is a recently-developed, massively-parallel, time-dependent, nonlinear macroscopic fluid modeling code. Spatial discretization uses high-order Spectral ELements on a logically rectangular grid, achieving exponential convergence of spatial truncation error while allowing domain decomposition for parallization and grid adaptation to localized structure and complex geometry. It has a fully implicit time step, allowing efficient and accurate treatment of flow and 2-fluid effects. Nonlinear system solution uses Newton-Krylov methods based on the PETSc library. Physics equations are expressed in flux-source form, allowing details of discretization to be separated from specification of those equations. 1D and 2D versions of the code are operational, the 1D code using a version of Adaptive Mesh Refinement (AMR), concentrating the grid in regions of sharp gradients. Two major improvements have been made to the code over the past year. Static condensation has been implemented for effective preconditioning, using small, local direct solves which parallelize perfectly to solve for higher-order components. Iterative solution of the resulting condensed global matrix uses an additive Schwarz incomplete LU factorization with overlap and fill-in as a preconditioner for the GMRES Krylov-subspace method, avoiding previously-encountered limits on convergence for large time steps. These methods have increased the speed of the code by a factor of order 1000. The second development is a new variational approach to 2D and 3D adaptive gridding. Conventional AMR, with a grid oblique to the magnetic field, fail to resolve strong anisotropy. A more effective approach is to align the grid with the magnetic field. Since non-axisymmetric fields have regions of multiple small islands and stochasticity, an exact point-wise flux coordinate system is not achievable. A variational approach gives a best-fit solution. Approximate flux surfaces are constructed from the generalized eigenfucntions of a large, sparse, real, symmetric, matrix, using the Cullum-Willoughby implementation of the Lanczos algorithm. The solution is periodically interpolated to the newly aligned grid, using high-order spectral elements to minimize interpolation error. Adaptation is achieved by packing the grid in one dimension, normal to the approximate flux surfaces, using methods developed in the 1D version of the code.