NIMROD Team Meeting Minutes
November 10, 2007

Development:

Charlson Kim presented a number of topics related to nimrod development and application by the Univ. of WA PSI-Center group. He showed that a hot particle population broadens the 1/1 eigenfunction, and he is testing the effect of varying the maximum particle velocity in the benchmark computation. With a sufficiently large maximum (numerical) velocity, the mode is completely stabilized. Work on the FLR stabilization of tearing modes in MST is progressing with the help of a new distribution function diagnostic. Trying to use a spatially localized hot-particle distribution is problematic, at least in initial trials. A new MHD study of LDX uses equilibria provided by the experimental group. Mesh packing of the nimrod mesh uses existing routines, and that helps reduce the number of elements significantly. However, there appear to be artifacts near the flux core resulting from interpolating from the equilibrium mesh to the nimrod mesh. Cihan Akcay has successfully reproduced the results on relaxation in a decaying HIT-SI equilibrium. Kim's future efforts will focus on use of high-order polynomials for the particles, improving parallelism, and computing the full hot-particle pressure tensor.

Eric Held gave an update on integral closures including work by Jeong-Young Ji and Mukta Sharma. Ji has derived a moment expansion for the Coulomb collision operator for arbitrary flow speeds in the small mass ratio approximation. Held has worked on completing the Chapman-Enskog like closure model including off-diagonal terms and neoclassical effects with trapping from mod-B variation. Simulating SSPX heat flow with open field lines requires a slight reformulation of the parallel temperature gradient computation; the integration by parts is replaced with a separate computation. This also provides greater accuracy, even with Braginskii, and comparisons show that biquartic elements with 22 Fourier components are needed to achieve convergence on the original cases. The discrepancy between Braginskii and integral heat flux is significant, but the resulting temperature profiles only differ by 10-15 eV. Making the computations run faster remains an important area of research.

Scott Parker has a new student, Jinhua Chen, working on low-moment kinetic MHD. The model uses fully kinetic ions via delta-f PIC, where the distortion may accumulate any of the low-order moments. The approach only assumes quasineutrality and zero displacement current, which are built into the Ohm's law. Tests computations reproduce all of the low-frequency wave branches for parallel propagation and ion Landau damping. This model can be used to study the kinetic response of ions in magnetic islands.

Scott Kruger is using Taylor-problem computations to test new infrastructure for boundary conditions and as a model problem for RMP. The computations are now running without producing div(B) errors, but there is some question on the treatment of n and T at the wall (presently handled with a little density diffusion). The computations will be extended to shear-flow conditions, two-fluid modeling, and eventually 3D. Much of the infrastructure will work for the resistive wall. In addition, a new version of source terms has been motivated by SWIM.

Srinath Vadlamani is interfacing nimrod with the PETSc library, which allows many solver options. These options are specified by command-line arguments, and a new petsc.f routine in the externals directory handles the calls from the nimrod solvers. Test cases with two processors run with either SuperLU or MUMPS called through PETSc; however, the PETSc interface is presently invoked only for real matrices. This is a limitation in the present multi-grid implementation (HYPRE), and the team discussed how to get support for our complex matrices. Besides interfacing for complex systems, the next steps are to complete testing of the triplet data format and run parallel scaling.

Project improvement:

Action items resulting from the discussion at the summer's team meeting were reviewed:

1. Make the input format for nimuw compatible with the developer's version. [Done]
2. Add nimuw as a branch of the nimdevel repository. [Done—see below]
3. Define interfacing for sources and closures. [Significant progress—see below]
4. Communicate development changes more frequently. [Progress]
5. Merge nimdevel and nimlite branches. [Done]
6. Make data initialization less block-type dependent. [Not done but lower priority]
7. Review progress on code development management at APS. [This discussion is it.]

Scott Kruger described revisions to the website using TRAC integration to facilitate uploading by developers. There remains a static (public) website, and the private site is intended for users and developers, but only Firefox works well at this point. Regarding the repository structure, Kruger described and demonstrated the nimfiles tool, where branches are based only on modified files. Regression testing is now operational, but more cases are needed. The testing check binary files according to a prescribed tolerance level. Successful comparisons usually show greatest discrepancy at block or domain borders. Merges with nimlite have been completed, and more groups of routines have been broken into separate files. Creating the nimuw branch of nimdevel moved files into the nimdevel directory structure, which facilitates regression testing.

Eric Held presented ideas on making the coupling of closures and sources as modular as possible. This includes hot particles, integral closures, Braginskii closures, SWIM-related development, and some aspects of radiation modeling. There was some discussion of whether model-specific data should be written to the dump files or to separate files with consensus going to the latter. Held proposed a new closures directory structure starting with subdirectories for the different models which can be used together. There was also discussion of how initialization would be handled. Held agreed to write-up the ideas and distribute for further comment.

Web machinery and instructions are now available for our case study, but a set of standards still needs definition. Dalton Schnack offered the g-mode as a guinea pig case.

Applications:

Richard Milroy presented MHD and two-fluid simulations related to FRCs. A study of acceleration for PHD and FRX-L uses implicit advection with the nonlinear diffusivity and finds little flux loss. A stability study of the n=2 mode compares growth rates with and without the Hall effect and toroidal magnetic field. The Hall effect is not especially significant, but toroidal field changes the structure of the modes. Developments needed for RMF has been completed, and initial computations show field penetration, but lack of toroidal preconditioning leads to long iteration for the Hall advance. Developments include finishing the n=2 computations and outflow boundary conditions, continuing the RMF studies, implementing Chodura resistivity, and investigating FRC formation and field conversion.

Val Izzo gave a preview of her invited talk on disruption mitigation. The computations use three separate continuity equations (electron, deuterium, and impurity ions) and temperature-dependent thermal conductivities. The impurity injection is approximated with a 1D model. Radiation modeling is not amenable to the scaling of S required for the fluid simulations, so the resistivity in Ohm's law differs from that used for Ohmic heating. Results show a slow propagation into the edge plasma followed by a quick global collapse of thermal energy. The collapse is consistent with experimental results and occurs as MHD instabilities make the plasma stochastic. Heat quickly conducts to regions where impurities radiate the energy. Relative to neon injection, helium injection leads to a long quench time, and background boron provides a significant amount of the radiation. More accurate boron modeling is needed.

Fatima Ebrahimi presented a derivation of the fluid g-mode instability at high k, which is important for modeling purposes. The new dispersion relation includes gyroviscosity and compressibility with a temperature gradient. NIMROD results agree well with this theory except near marginal conditions at moderate beta. Mio Suzuki is performing further convergence tests, but the discrepancy may be associated with boundary conditions. Ping Zhu has expanded the analysis to include the Hall effect.

Ping Zhu presented an effort to read ESC (Zakharov and Pletzer) equilibria into nimset. Unlike other equilibrium codes, ESC will generate a flux-aligned mesh from a subroutine call. This will lead to ballooning-mode computations in the relatively simple circular-cross-section tori for comparison with analytical nonlinear analysis as an extension of his work on line-tied ballooning.

Jim Reynolds summarized his dissertation research on PPCD in the RFP. The computations consider self-consistent nonlinear evolution, and they are diagnosed with a combination of linear analysis of the symmetric state and computation of power flow among groups of modes and the mean field. For the dominant core modes and edge-resonant m=1 modes, the initial response from the poloidal electric field is the power transfer to the mean field. In contrast, m=0 modes are first affected by loss of nonlinear coupling. When the axial electric field (loop voltage) is decreased, the first response is still from the poloidal E pulse, but the reduced axial drive maintains stability for a longer period of time.

Alexei Pankin presented edge-physics modeling done in collaboration with the CPES center. The center's XGC0 code performs Monte Carlo computations of ion orbits, and charge is accumulated on a 1D flux-surface grid to generate ExB flows. This information is coupled to an equlibrium solver, ELITE for linear stability, and M3D/NIMROD for crash information via the Kepler Workflow software. Benchmarking NIMROD with ELITE shows reasonably good agreement at high-n, but not at n ~4-10, where the 1/n expansion in ELITE may not be accurate. Further study is warranted, however.

Tom Jenkins described the SWIM collaboration for coupling RF current drive to model stabilization of NTMs. He reviewed the emerging theoretical framework that is appropriate for ECCD. While the ultimate goal is to model RF propagation and deposition, the first results are on adding an ad hoc source to the 2/1 classical tearing. The source excites and Alfvenic response that spreads current over the flux surface, and it does reduce the size of a saturated island.

Alfonso Tarditi described applications for space technology that include lightning, plasma actuators for airfoils, and MHD propulsion. His students are NASA employees who want to complete graduate degrees.

Rostom Dagazian requested an identification of milestones for the project. Sovinec will check if that can be together with CEMM milestones. An important change on the horizon is that the traditional SciDAC projects will end as separate projects after the cycle that has just been renewed. They are expected to become part of the FSP effort.