NIMROD Team Meeting Minutes, October 29, 2016
San Jose, California

Computational developments:

Carl Sovinec reviewed the least-squares formulation for the ideal parts of the particle density and temperature equations, first presented at last team meeting. After this review, he noted that non-ideal terms can be added in either a time-split formulation or by adding auxiliary fields for the diffusive flux densities. The former uses Galerkin projections for the diffusive parts, so coding for NIMROD's standard computations can be reused, and this has been implemented. Sovinec described how least-squares has also been applied to the magnetic advance (in a test branch of nimuw) and presented linear and nonlinear test results computed with this method. Possible advantages for the two-fluid magnetic advance were also noted. A separate topic is numerical noise associated with frequent time-step changes. Dan Barnes suggested a gradual adjustment of the semi-implicit coefficient to help avoid sudden perturbations when the time-step changes.

Scott Kruger provided a review of the Fluxgrid code. It was originally written by Alan Glasser for importing equilibria into DCON. At the time, direct equilibrium solvers were seldom sufficiently accurate for stability studies, so a lot of Fluxgrid was written to map results of inverse equilibrium solves. Kruger modified the code to use fewer mapping steps and thereby reduce interpolation error. When applying Fluxgrid to direct-solve data, the coding that is used is in read_direct.f, grid.f, and direct.f, and most of it loads the dir_type data structure. The flux label is R on the outboard side. Outside the confined-plasma region, the mesh is generated via geometric progression, with a boundary placed at a proportionate distance from the sepatrix, and fields are then interpolated. Jacob King has been developing ways to incorporate non-constant P and J in the SOL. When refitting using FGNIMEQ, the dominant source of error is the flux function along the boundary, which is not allowed to change.

Physical model development:

Jeong-Young Ji is developing parallel closure relations for inhomogeneous magnetic field. Here, he solves the drift-kinetic equation, via the moment method, along field-lines using finite-difference numerics over the poloidal angle, incorporating toroidal-geometry effects. The integrated results are patched to collisionless results when taking the low-collisionality limit. The drives for the DKE are the flux-normal gradients in background pressure and temperature. Ji showed the behavior of the DKE solutions as normalized collisionality is varied, and he demonstrated convergence by taking an increasing number of moments. Future steps include generalizing the background distribution in the DKE, combining the moment and collisionless results, and allowing general flux-surface geometry.

Sina Taheri presented his development work to incorporate dynamic neutral modeling in NIMROD. Possible applications include tokamak boundary dynamics, disruption, and disruption mitigation. So far, the atomic modeling includes electron-impact ionization, radiative recombination, and resonant charge exchange. The radiation modeling assumes an optically thin response, i.e. loss. The plasma-neutral interactions include density production, friction, and heat exchange. Electron-neutral interactions also affect electrical resistivity. Taheri's test cases include coronal equilibrium, a balance between ionization and radiative recombination. In test computations with flow, ion and neutral velocities approach each other, but there are oscillations. Taheri is also checking conservation properties of the computations.

Matt Beidler discussed his implementation of time-dependent magnetic boundary conditions for computations of resonant magnetic perturbation (RMP). Temporal dependence is realistic for modeling experiments, and it can help avoid numerical noise that arises during initial transients with sudden application of perturbations. He applies the B-normal and E-tangential fields consistently, the former through a new routine that changes nodal data along the surface and the latter through the surface integrals for the B-advance. The distribution of E-tangential can accommodate an arbitrary electrostatic component, and Beidler chooses to set that to zero. He has confirmed the new modeling in forced magnetic reconnection in slab geometry and is now applying it to study mode-locking bifurcation.

Applications:

Jacob King discussed open questions from his study of quasi-harmonic oscillations (QHO) in DIII-D. The study considers low-n modes but uses an annular domain to avoid sawtooth oscillations. The inner boundary of the annulus effectively provides sources of particles and heat. King developed numerical diagnostics to analyze the fluctuation-induced power flow in his simulations. He averaged simulation results over a 0.06 ms window and found that the total has a peak in radius that is at least an order of magnitude too large relative to experimental input power. However, for computational practicality his simulations also have unphysically large dissipation coefficients, which would alter the effective input. He is also considering plasma rotation and its effects on frequency spectra; two-fluid effects may be essential.

Joshua Sauppe gave a dry run of his APS-DPP invited presentation on the coupling of current-density and flow evolution during magnetic relaxation. Experimentally, Joe Triana is using a new deep-insertion probe on low-current discharges in the Madison Symmetric Torus (MST) to measure profiles of J and B fluctuations. Also, ensemble-averaged results show that changes in the large-scale core $J_{\|}$ and changes in core $V_{\|}$ are in the same direction during relaxation events. This is not the case in the first relaxation event in two-fluid simulations. Given the nature of initiating the simulations, first events may not be representative; they effectively disrupt a quasi-single helicity (QSH) state. However, at least some of the subsequent events in simulations show the orientations of the experimental observations. Sauppe's presentation also summarized highlights from his already published study of power and helicity flow. A third physics topic is that relaxation in two-fluid simulations actually puts more energy into perpendicular flows than in parallel flows.

Eric Howell presented his efforts to model disruption in Auburn's Compact Toroidal Hybrid (CTH) experiment and characterize effects that change with the ratio of vacuum- and plasma-current-induced rotational transform (f). Experimentally, with large f-values, operation through $q(a)<2$ is possible, but 3/2 or 4/3 modes lead to disruption. Statistics show that disruptivity decreases with f, but disruption tends to occur during decay. Computationally, Howell has used reconstructions of a particular discharge. Different MHD activity, including island coalescence and sawtoothing, is reproduced in the simulations. The effects of the n=5 imposed fields are readily apparent as islands (flat spots) in the transform profile. Disruption from the 3/2 and 4/3 modes is not yet reproduced. The modes appear but seem to saturate at small amplitude.

Kyle Morgan presented his recent simulation efforts for the HIT-SI3 experiment at the Univ. of Washington, where an important physics topic is the effect of using different phasings among the three sets of injectors. He uses two-fluid models with and without the effects of finite plasma-beta. The input waveforms are matched to experiment, and the buildup of n=0 fields generally agrees with experiment. He described the use of biorthogonal decomposition in time and space, in order to make comparisons with experimental analysis. A set of metrics has been developed to quantify the comparisons. The first three spatial vectors contain more than 95% of the signal, where there is good agreement between simulations and experiments for each of the three phasings. There is significant disagreement with the remaining vectors, however. Morgan noted that simulations with finite pressure tend to do better in terms of reproducing the centroid of the current-density distribution.

Torrin Bechtel gave an update on his study of finite-beta effects in stellarators. He is running computations of two configurations, a CTH-like configuration with enhanced vacuum transform and an $l = 2$, $m = 10$ torsatron with iota-bar just above 1/2 at the magnetic axis. He has tested spatial-resolution requirements using limited periodicity and compared increasing toroidal resolution vs. increasing the number of integration points in toroidal angle. He has also run full-periodicity computations that are initialized from limited-periodicity results. With increased resolution, stable equilibria can be obtained. A new collaboration with NIFS in Japan seeks to benchmark soft-beta limits with the HINT2 code. Bechtel is not yet seeing the HINT2 predictions of beta limits, but he is checking the heating and sensitivity to transport coefficients.

Brian Cornille presented his simulation-based study of tokamak discharges in MST, with and without resonant magnetic perturbation (RMP). He uses the RB_ϕ profile from MSTFIT but resolves with NIMEQ, specifying $P = 0$, since the discharges have very low plasma-beta. The vacuum-field distributions for the perturbations are imposed as part of the initial conditions, and their surface distributions are maintained through boundary conditions. Cornille showed how RMPs of different m-number (m=1, 2, and 3) affect the magnetic topology differently during the course of simulated sawtooth oscillations. He also scanned the amplitude of the m=3 vacuum perturbation to uncover the different helicities that lead chaotic fields in the edge at full amplitude. Cornille also proposed a mechanism for how the m=3 perturbations, together with sawtooth oscillations, deconfine runaway electrons in the experiment.