Final Technical Report for "Center for Gyrokinetic Particle Simulation of Turbulent Transport," DE-FC02-05ER54816

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This is the Final Technical Report for University of Colorado's portion of the SciDAC project "Center for Gyrokinetic Particle Simulation of Turbulent Transport." This is funded as a multi-institutional SciDAC Center and W.W. Lee at the Princeton Plasma Physics Laboratory is the lead Principal Investigator. Scott Parker is the local Principal Investigator for University of Colorado and Yang Chen is a Co-Principal Investigator. This is Cooperative Agreement # DE-FC02-05ER54816. Research personnel include Yang Chen (Senior Research Associate), Jianying Lang (Graduate Research Associate, Ph.D. Physics Student) and Scott Parker (Associate Professor). Research includes core microturbulence studies of NSTX, simulation of trapped electron modes, development of efficient particle-continuum hybrid methods and particle convergence studies of electron temperature gradient driven turbulence simulations.

Recently, the particle-continuum method has been extended to five-dimensions in GEM. We find that actually a simple method works quite well for the Cyclone base case with either fully kinetic or adiabatic electrons. Particles are deposited on a 5D phase-space grid using nearest-grid-point interpolation. Then, the value of delta-f is reset, but not the particle's trajectory. This has the effect of occasionally averaging delta-f of nearby (in the phase space) particles. We are currently trying to estimate the dissipation (or effective collision operator).

We have been using GEM to study turbulence and transport in NSTX with realistic equilibrium density and temperature profiles, including impurities, magnetic geometry and ExB shear flow. Greg Rewoldt, PPPL, has developed a TRANSP interface for GEM that specifies the equilibrium profiles and parameters needed to run realistic NSTX cases. Results were reported at the American Physical Society – Division of Plasma Physics, and we are currently running convergence studies to ensure physical results. We are also studying the effect of parallel shear flows, which can be quite strong in NSTX.

Recent long-time simulations of electron temperature gradient driven turbulence, show that zonal flows slowly grow algebraically via the Rosenbluth-Hinton random walk mechanism. Eventually, the zonal flow gets to a level where it shear suppresses the turbulence. We have demonstrated this behavior with Cyclone base-case parameters, except with a 30% lower temperature gradient. We can demonstrate the same phenomena at higher gradients, but so far, have been unable to get a converged result at the higher temperature gradient. We find that electron ion collisions cause the zonal flows to grow at a slower rate and results in a higher heat flux. So, far all ETG simulations that come to a quasi-steady state show continued build up of zonal flow, see it appears to be a universal phenomena (for ETG).

Linear and nonlinear simulations of Collisional and Collisionless trapped electron modes are underway. We find that zonal flow is typically important. We can, however, reproduce the Tannert and Jenko result (that zonal flow is unimportant) using their parameters with the electron temperature three times the ion temperature. For a typical weak gradient core value of density gradient and no temperature gradient, the CTEM is dominant. However, for a steeper density gradient (and still no temperature gradient), representative of the edge, higher k drift-waves are dominant. For the weaker density gradient core case, nonlinear simulations using GEM are routine. For the steeper gradient edge case, the nonlinear fluctuations are very high and a stationary state has not been obtained. This provides motivation for the particle-continuum algorithm. We also note that more physics, e.g. profile variation and equilibrium ExB shear flow should be significantly stabilizing, making such simulations feasible using standard delta-f techniques. This research is ongoing.

Papers and Presentations

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