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Progress on full radius gyrokinetic turbulence simulations and prospects for treating transport time scales with GYRO*

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Abstract

GYRO is a physically comprehensive continuum global gyrokinetic code for simulating turbulent transport in tokamaks. Beyond the now standard ion-temperature-gradient (ITG) mode turbulence, the code includes trapped and passing electrons with pitch angle collisions, electromagnetic finite-β perturbations, real geometry from Miller local equilibrium, $E\times B$ and parallel flow shears. It operates at finite (but small) $\rho_* = \rho_i/a$ and treats general profile shear stabilization in a WKB-like approximation. Tremendous progress has been made since the project began in 1999. At the 2002 Sherwood meeting, we reported comprehensive simulations of Bohm-scaled DIII-D L-mode ρ_*-scaled discharges which compared within a factor 2 of experimental transport levels. These simulations were limited to 80 ρ_i radial slices (one-third the minor radius), $\mu = \sqrt{m_i/m_e} = 20$, and required five 24-hour restarts on 128 processors of the NERSC IBM SP (seaborg.nersc.gov). Timesteps were limited to about 1/10th the nonlinear ITG adiabatic-electron timestep. Since then, a better data distribution scheme has allowed processor scaling beyond 512 processors, with a full global electromagnetic simulation now achievable in a single 24-hour run. As we moved to larger radial slices and larger μ, the 4th-order Runge-Kutta method was plagued by numerical difficulties connected with extremely fast “electrostatic” Alfvén modes. This caused the development of weak n=0 “radial box” instabilities. A new 3rd order implicit-explicit Runge-Kutta method splits off the stiff linear parallel electron motion for implicit treatment, stepping over the troublesome modes, and allowing near full radius 240 ρ_i DIII-D runs with physical $\mu = 60$ (deuterium) at significantly larger time steps. The DIII-D L-mode simulations are now closer to experimental levels. We will shortly add $\delta B_{||}$ perturbations for NSTX high-β simulations, and implement a better formulation of the parallel shear Kelvin-Helmhotz drive at finite Mach number. We believe that the timestep is presently limited by the explicit nonlinear magnetic flutter term. Nevertheless, with full radius operation, we have started to assess prospects for treating “turbulence on transport time scales”. Gyrokinetic codes are too expensive to run longer than a few percent of the transport confinement time. However, given the stiff nature of core transport, it is more accurate to predict profiles given experimental flows. An interaction with an outer” transport code time scale loop, which adjusts the profiles, to the given sources should make this possible.

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