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Simulation of EP-driven nonlinear collective effects using Landau closure methods

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The long time-scale nonlinear simulation of energetic particle (EP) instabilities is critical to studies of fast ion transport since this allows inclusion of mode-coupling induced zonal flows/currents, and transfers of energy to longer and shorter scales. These processes, which are important in evaluating the impact of EP instabilities on heating efficiency, can evolve over much longer timescales than the initial growth and saturation. Also, the predator-prey cycles associated with zonal flow/current effects drives significant intermittency, which is important in the consideration of heat flux variations on plasma-facing components. The FAR3d global gyro-Landau moments model provides an efficient kinetically-closed model for simulation of energetic particle driven instabilities. FAR3d uses hybrid MPI/OpenMP parallelization methods that allow good scaling to the strongly coupled, high toroidal mode number regime of ITER. This work presents the first sustained long-term (˜ 50,000 Alfvén times) FAR3d simulations of the above effects, demonstrated using selected discharges from the DIII-D tokamak. The initial growth, saturation levels (peak \delta B_{\theta}/B ˜ 0.001, \delta Te ˜ 3.4 eV), frequency spectrograms (f ˜ 90 kHz), and intermittency (periodic burst interval ˜ 0.1 msec, time averaged bursts 1 to 2 msec) are in similar ranges as observations. Two-dimensional zonal structures are obtained in the saturated phase for both the poloidal flows and perturbed toroidal currents. Collective EP transport levels and fast ion density gradient flattening are calculated and show significant levels of EP transport. Future areas for improvement in the FAR3d model include extension to higher moments, improved treatment of phase mixing from drift resonances, transport evaluation using tracer particle orbits, and closure relations optimized for the effect of non-Maxwellian distributions.

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