A Gyro-Landau-Fluid Model for Trapped and Circulating Particles*

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Abstract

Gryo-Landau-Fluid (GLF) models have been shown to give an accurate approximation to the kinetic linear growth rates of drift-ballooning modes in Tokamaks.[1-3] GLF models for separate passing and trapped fluids with collisional exchange were the bases of the successful quasilinear transport model GLF23.[4] However, GLF23 is limited to a small range of magnetic shear and to shifted circle geometry due to its use of a trial wave function fitted to obtain growth rates approximating exact kinetic results. A Hermite basis function method for solving the GLF eigenmode equations has been developed to replace the trail wavefunction approach. Experimental situations in which both electron and ion modes are unstable in overlapping wavenumber ranges are not uncommon. GLF23 assumed a stable gap between the electron temperature gradient (ETG) and ion temperature gradient (ITG) modes. Treating the overlapping case requires a new set of GLF equations. A new system of GLF equations is presented here with three moments for trapped particles and six moments for passing particles. The trapped particles have only even moments since the odd moments are assumed to be bounce averaged to zero. The closure of the highest moments yields coefficients which are functions of the trapped particle fraction. These coefficients are fit by minimizing the error between the GLF response functions and the exact kinetic result as was done in Ref. 3 for a six moment gyrofluid model for circulating particles. A model for the boundary between those trapped particles which can bounce average a given wave and those which can have a Landau resonance with the wave is used. This model gives the fraction of bounce averaging particles which is a functions of the parallel wavenumber of the wave but not its frequency. Using this bounce averaging fraction in place of the trapped fraction gives a model which is valid over the full spectrum of driftwave eigenmodes and is not restricted to modes with frequency below the bounce frequency. Thus, the final system of GLF equations for ions and electrons is valid from the lowest frequency trapped ion modes all the way up to the highest frequency ETG modes. Benchmarking of the linear growth rates with a large database of gyrokinetic growth rates will be shown. The implications of the overlapping of electron and ion instabilities on transport will be explored at the quasilinear level with the new model. The GLF model gives a much faster calculation of the linear eigenmodes than a gyrokinetic initial value code. The new GLF model has applications as an analysis tool for experimental discharges (both growth rates and critical gradients) and as the core eigenmode solver in a quasilinear transport model [4].

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