Global gyrokinetic simulation of ion temperature gradient driven turbulence in plasmas with canonical Maxwellian distribution

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A global gyrokinetic toroidal particle code for a 3D nonlinear simulation (GT3D) has been developed to study the ion temperature gradient driven - trapped electron mode (ITG-TEM) turbulence in reactor relevant tokamak parameters [1]. In GT3D, gyrokinetic ions and drift-kinetic (trapped) electrons are solved using a finite-element PIC method. The code uses a new δf method based on a canonical Maxwellian distribution $F_{CM}(P_\Psi, \varepsilon, \mu)$, which is defined by three constants of motion in the axisymmetric toroidal system, the canonical angular momentum $P_\Psi$, the energy $\varepsilon$, and the magnetic moment $\mu$. A quasi-ballooning field solver enables linear and nonlinear high-m,n global calculations with a good numerical convergence. Conservation properties are improved by using the optimized particle loading. The code has been optimized for massively parallel scalar and vector machines, and it operates with a high processing efficiency and scalability on the JAERI Origin3800 system and on the Earth Simulator.

From comprehensive linear global analyses over a wide spectrum ($n=0$–$100$) in reactor relevant tokamak parameters ($a/\rho_i=320$–$460$), it is found that the reversed shear configuration produces an effective stabilizing effect on the ITG mode in the $q_{\text{min}}$ region through global effects [1]. In the preliminary linear calculations with drift-kinetic (trapped) electrons, it is confirmed that the ITG-TEM mode spectrum obtained from GT3D qualitatively agree with the former results obtained using a global gyrokinetic spectral code. In the nonlinear calculations of the ITG turbulence with the Cyclone base case parameters [2], it is found that the new method based on $F_{CM}$ can simulate a zonal flow damping correctly, and that zonal flow oscillations, which often grow rapidly in a conventional code based on a local Maxwellian distribution $F_{LM}(\Psi, \varepsilon, \mu)$, do not appear in the nonlinear regime [1]. Through linear zonal flow damping tests [3], spurious driving effects on zonal flows in the conventional code with $F_{LM}$ are identified.