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 $F_{CM}(P_\varphi,\varepsilon,\mu)$, which is defined by three constants of motion in the axisymmetric toroidal system, the canonical angular momentum P_φ, the energy ε, and the magnetic moment μ. 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/ρ_{ti}=320~460), it is found that the reversed shear configuration produces an effective stabilizing effect on the ITG mode in the q_{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.

[1] Y. Idomura et al., Nucl. Fusion **43**, 234 (2003).

[2] A.M. Dimits et al., Phys. Plasmas **7**, 969 (2000).

[3] M.N. Rosenbluth et al., Phys. Rev. Lett. **80**, 724 (1999).