Recent extensions of a gyrokinetic Vlasov simulation code for helical plasmas

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Gyrokinetic simulation has now been recognized as an inevitable tool not only for quantitative investigation of plasma turbulent transport but also for enhancing predictability on confinement properties of magnetic fusion experiments. A flux tube gyrokinetic code, GKV, has been applied to simulations of plasma turbulence in non-axisymmetric systems, such as the Large Helical Device (LHD). While simulation studies based on the simplified flux tube geometry have successfully clarified the zonal flow enhancement in the ion temperature gradient (ITG) turbulence in an optimized LHD configuration [1], further developments are demanded for more detailed and efficient investigations on the turbulent transport in helical systems. First, we have implemented the GKV-X code so as to incorporate the complicated geometrical factors of helical configurations obtained by the VMEC equilibrium computations [2], which enables us to directly compare the gyrokinetic simulations with the LHD experiments. Second, we have developed a hybrid time-integration scheme of the semi-Lagrangian and the additive semi-implicit Runge-Kutta method for the flux tube model [3]. The new scheme is quite efficient and, is free from the CFL condition in the linear regime. In helical systems, parallel particle motions passing a helical ripple severely restrict the time-step size, which is overcome by utilizing the semi-Lagrangian approach. The magnetic drift term is dealt with implicitly but with no matrix inversion, which makes the semi-implicit computation quite efficient. Third, with the aim of investigating effects of the equilibrium-scale radial electric field on zonal flows and turbulence in helical systems, field line label dependence of the confinement field strength has been incorporated in an extended version of the GKV code [4], which is now re-formulated as a multi-scale coupling model. Finally, we have developed a method for analyzing the entropy transfer process among turbulence and zonal flows. The new analysis clarifies a catalytic role of zonal flows in the entropy transfer process from low to high radial wavenumber components of the ITG turbulence [5]. Future extensions of the GKV/GKV-X codes will also be discussed at the conference.

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