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Turbulence simulation with a bounce-averaged kinetic electron model in general tokamak geometry

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Trapped particles in a toroidal magnetic geometry undergo bounce motions. The second adiabatic invariant associated with the bounce motion allows one to formulate bounce-averaged kinetic (BK) equations [1,2], which provide reduced kinetic descriptions. Though the BK electron model has been employed in kinetic turbulence simulation codes, the implemented BK equations are derived for analytic magnetic geometries.

In this work, we extend the BK electron model to be applicable in experimental tokamak magnetic geometries and implement it on the global particle-in-cell gyrokinetic code gKPSP [3]. We perform a benchmark study of the updated BK model against the gyrokinetic electron model in flux-tube codes, CGYRO [4] and GENE [5]. From the comparisons among the simulations based on the local parameters of a KSTAR L-mode plasma, we confirm a reasonable agreement among the linear results from the different codes, albeit some discrepancies still remain. In the nonlinear gKPSP simulation with a narrow plasma gradient region whose width comparable to the mode correlation length, ion and electron heat fluxes are compatible with those calculated by CGYRO, as shown by Fig. 1. However, with an unstable region sufficiently wider than the mode correlation length, the nonlinear gKPSP simulation predicts 2–3 times larger turbulent heat fluxes than those from CGYRO. Taking into account the differences between the flux-tube and global simulations, the overall agreement is encouraging for further validation and development of the BK electron model.

References

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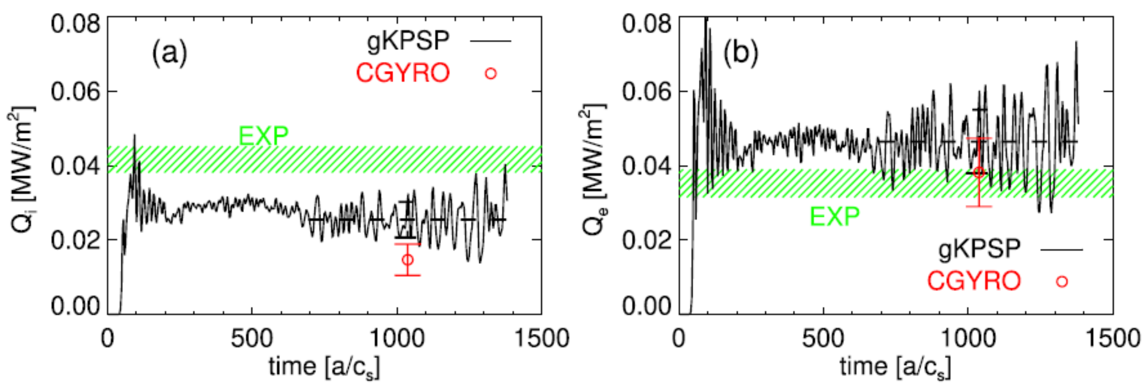

Figure 1 Time histories of heat fluxes of ions (a) and electrons (b) from a nonlinear gKPSP simulation with the plasma gradient region width W=0.1. Heat fluxes obtained from a CGYRO simulation are shown by the red symbols. The power balance analysis of the experimental plasma are displayed by the green shaded bands.