ETG turbulence coupled to ITG/TEM turbulence*

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This work reports on GYRO [1] simulations of small-scale ETG fluctuations coupled large-scale ITG/TEM turbulence. In order to keep the problem numerically tractable, the simulation community has typically assumed that ions are exactly adiabatic (the so-called **ETG-ai** model) so that high-$k_\perp$ electron transport from ETG effectively decouples from low-$k_\perp$ ITG/TEM transport. However, there has been considerable speculation on the need for nonlinear coupling between ITG/TEM and ETG turbulence [2]. To this end, we have made the necessary modifications and optimizations in GYRO in order to rigorously simulate the ITG/TEM-ETG coupling. We tentatively define ETG transport as that which arises from $k_\theta \rho_i > 1$. In the ETG range, ions are almost exactly adiabatic. To get finite χ_i or D, or to describe ITG/TEM-to-ETG coupling, we require kinetic (nonadiabatic) ions.

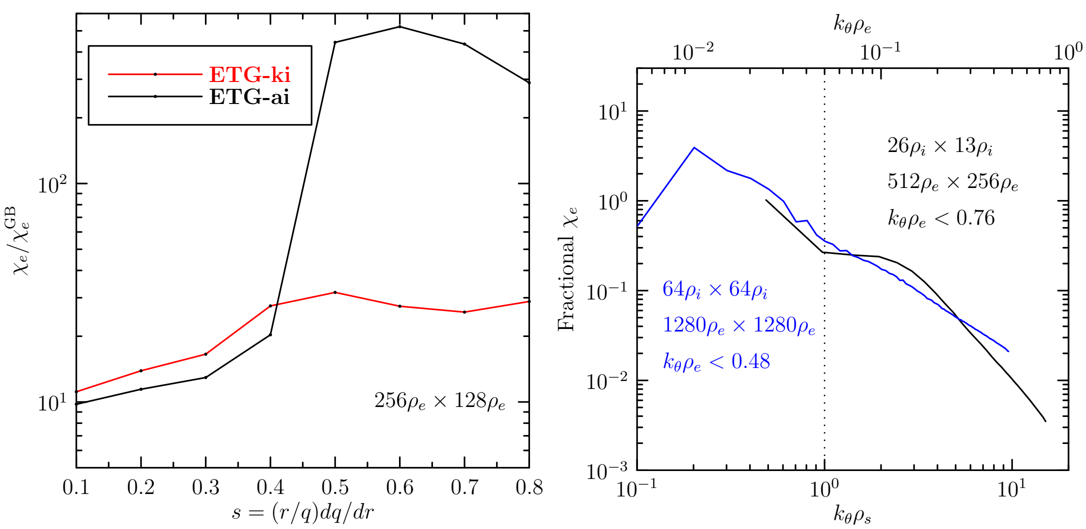

Fig. 1. (a) Small electron-scale-box simulations of the *Cyclone base case*, comparing χ_e computed with the ETG-ai model (dotted red curve) with χ_e computed with the ETG-ki model (black curve) as a function of magnetic shear, s. The ETG-ai results for $s > 0.4$ are unphysical, while the ETG-ki simulations saturate normally there. (b) Large-box, coarse grid ETG simulations compared with small-box, fine grid simulations. Good spectral overlap is obtained.

Our results, briefly summarized, indicate that

1. GYRO simulations show that properly saturated states using the ETG-ai model [3] do not exist beyond $s \sim 0.4$, as shown in Fig. 1a (results for which $\chi_e/\chi_e^{\mathrm{GB}} > 10^2$ are **unphysical**). Although PIC simulations have previously found finite saturated values for χ_e at $s = 0.8$, this was shown to be a result of error due to discrete particle noise [4-5].
2. Good spectral overlap is obtained in coupled ITG/TEM-ETG simulations with different box and grid sizes (see Fig. 1b).
3. Electron heat transport is not significantly enhanced by ETG coupling, except when ITG/TEM activity is reduced due to equilibrium $\mathbf{E}\times\mathbf{B}$ shear. This result supports the hypothesis that ETG transport is the key electron transport mechanism within an ion transport barrier (ITB).
4. There appears to be minimal downward ETG cascade (adding successively higher $k_\perp$ ETG drive does not affect the low-$k_\perp$ ITG/TEM transport).

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