Coupled ion temperature gradient and trapped electron mode to electron temperature gradient mode gyrokinetic simulations*

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Abstract. Electron temperature gradient (ETG) transport is conventionally defined as the electron energy transport at high wave number (high-k) where ions are adiabatic and there can be no ion energy or plasma transport. Previous gyrokinetic simulations have assumed adiabatic ions (ETG-ai) and work on the small electron gyroradius scale. However such ETG-ai simulations with trapped electron often do not have well behaved nonlinear saturation unless fully kinetic ions (ki) and proper ion scale zonal flow modes are included. Electron energy transport is separated into ETG-ki at high-k and ion temperature gradient - trapped electron mode (ITG/TEM) at low-k. Expensive (more compute-intensive), high-resolution, large-ion-scale flux-tube simulations coupling ITG/TEM and ETG-ki turbulence are presented. These require a high effective Reynolds number $R \equiv [k(\max)/k(\min)]^2 = \mu^2$ where $\mu = [\rho_{si}/\rho_{si}]$ is the ratio of ion to electron gyroradii. Compute times scale faster than μ^3. By comparing the coupled expensive simulations with (1) much cheaper (less compute-intensive), uncoupled, high-resolution, small, flux-tube ETG-ki and with (2) uncoupled low-resolution, large, flux-tube ITG/TEM simulations, and also by artificially turning "off" the low-k or high-k drives, it appears that ITG/TEM and ETG-ki transport are not strongly coupled so long as ETG-ki can access some non-adiabatic ion scale zonal flows and both high-k and low-k are linearly unstable. However expensive coupled simulations are required for physically accurate k-spectra of the transport and turbulence. Simulations with $\mu \geq 30$ appear to represent the physical range $\mu > 40$. ETG-ki transport measured in ion gyroBohm units is weakly dependent on μ. For the mid-radius core tokamak plasma parameters studied, ETG-ki is about 10% of the electron energy transport, which in turn is about 30% of the total energy transport (with negligible $E \times B$ shear). However at large $E \times B$ shear sufficient to quench the low-k ITG/TEM transport, the high-k tail of the ETG-ki transport survives. Decreasing the trapping to minimize the TEM opens a stability gap between ITG and ETG. High-k ETG transport driven by low-k ITG instability in an ETG linearly stable plasma is demonstrated.

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