Abstract

Equations which describe the evolution of volume-averaged gyrokinetic entropy are derived and added to GYRO, an Eulerian gyrokinetic turbulence simulation code. In particular, the creation of entropy through spatial upwind dissipation (there is zero velocity-space dissipation in GYRO) and the reduction of entropy via the production of fluctuations are monitored in detail. This new diagnostic has yielded several key confirmations of the validity of the GYRO simulations. First, fluctuations balance dissipation in the ensemble-averaged sense, thus demonstrating that turbulent GYRO simulations achieve a true statistical steady state. Second, at the standard spatial grid size, neither entropy nor energy flux is significantly changed by a sixteen-fold increase (from 32 to 512 grid points per cell) in velocity-space resolution. Third, the measured flux is invariant to an eight-fold increase in the upwind dissipation coefficients. A notable conclusion is that the lack of change in entropy with grid refinement refutes the familiar but incorrect notion that Eulerian gyrokinetic codes miss important velocity-space structure. We also comment on the issues of density and energy conservation and their relation to negligible second-order effects such as the parallel nonlinearity.