Verification of XGC, a gyrokinetic edge particle code

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Verification of a large complex code is an important part of the code development. Its importance cannot be overemphasized.

The gyrokinetic edge particle code package XGC contains XGC-0 and XGC-1, which simulates plasma and neutral species in the tokamak edge region, spanning over the pedestal, the magnetic separatrix surface and X-points, and the material wall. The original XGC-0 was a full-f ion guiding center code in which the particle motion was in a 3D equilibrium magnetic field, but the ion-root solution E_r was obtained inside the separatrix in the radial direction only (perpendicular to the flux surfaces). Due to the neglect of the electron parallel motions, the electric potential profile in the scrape-off layer was hand-prescribed in the original XGC-0. The XGC-0 is then upgraded to include the electron parallel motions, which allows the radial electric field solution in the scrape-off layer, as well as in a 3D perturbed magnetic field.

XGC-1 electrostatic turbulence code has been developed out of XGC-0 by adding the gyrokinetic and 3D electric field capabilities. When averaged over the toroidal and poloidal fluctuations, XGC-1 can be reduced to produce the 2D axisymmetric equilibrium solutions, including the self-consistent 2D electric field and plasma flow profiles. XGC-1 can also run in the delta-f mode to reproduce the conventional ITG modes in the core plasma.

In this report we will present various verification examples which we exercised in the course of XGC-0 and XGC-1 developments. The verification includes single particle motions in a spatio-temporally varying radial electric field, ion heat conductivity, neoclassical flow generation, manufactured charge distribution, GAM, core ITG modes, and zonal flow. Experimental validation will also be discussed.