Improving accuracy and conservation properties in gyrokinetic simulations

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Gyrokinetic models are a main tool to describe and understand the dynamics of Tokamak plasma. These models are fundamentally multidimensional and lead to huge computational requirements. The GYSELA code is a non-linear 5D global gyrokinetic full-f code which performs flux-driven simulations of ion temperature gradient driven turbulence (ITG) in the electrostatic limit with adiabatic electrons. It solves the standard gyrokinetic equation for the full-f distribution function, i.e. no assumption on scale separation between equilibrium and perturbations is done. A 5D Vlasov equation is self-consistently coupled to a 3D quasineutrality equation. Many features are included to improve the physical model as much as possible, such as heat/vorticity sources, collision operators.

Parallel computers are needed to run such kind of simulations. In order to step up the code and the physics at reduced computational costs, we design improved numerical methods and new parallel algorithms. Testing and checking such large parallel codes is complex. Furthermore, to gain confidence in the code, one has to build test suites to verify that mathematical and physical properties are well preserved.

We will present methods that improve the semi-Lagrangian scheme in terms of mass and energy conservations. It is not so simple to model the core limit near the Scrape-Off Layer, the impact of boundary conditions in radial direction will be discussed. The gyrokinetic Vlasov equation admits stationary solutions, a set of equilibrium distribution functions. We will examine procedures to construct such equilibrium states, and how we can enhance the accuracy of the Vlasov solver with this information. Notably, we have gain accuracy on the interpolation scheme using a δf representation. These investigations have allowed us to define reference simulation runs. It eases benchmarking and validation issues for 5D gyrokinetic simulations.

References

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