Benchmark of a semi-Lagrangian and a Lagrangian code for gyrokinetic simulations

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Gyrokinetic theory, based on the Vlasov-Maxwell equations, is the natural framework to understand microinstabilities behavior, where the typical frequencies and spatial gradient scales allow us to average out the fast particle gyromotion. Numerical simulations based on the gyrokinetic equations are fundamental instruments for the study of plasma turbulence. They provide us with a deeper insight on turbulent transport mechanisms and they will eventually allow us to simulate discharges in the International Thermonuclear Experimental Reactor (ITER). In order to provide reliable physical results, the numerical codes have to be benchmarked on the basis of a well known set of parameters and demonstrate their ability to correctly simulate basic phenomena. In the present work, the gyrokinetic code GYSELA[1] is benchmarked against results from the gyrokinetic code ORB5[2] for parameters inspired by the CYCLONE base case.

GYSELA is a global nonlinear electrostatic code which solves the gyrokinetic equations in a five dimension phase space with a semi-Lagrangian method. The purpose of the semi-Lagrangian method is to take advantage of both the Lagrangian and Eulerian approaches. In this approach the mesh grid is kept fixed in time in the phase space (Eulerian method) and the Vlasov equation is integrated along the trajectories (Lagrangian method) using the invariance of the distribution function along the characteristics. A good description of the phase space is thus obtained, in particular in regions where the density is low, as well as an enhanced numerical stability.

ORB5 is a global nonlinear electrostatic code based on the Lagrangian method. The five dimensional particle phase space is sampled with a Particle In Cell (PIC) scheme and a finite element scheme (FEM) is used for the Poisson solver.

The particular interest in this benchmark resides in the fact that both codes are global and in both schemes neither the temperature, nor its gradient, nor the heat flux are constrained. Therefore, heat fluxes and relaxation of temperature profiles can be directly compared.

[1] V. Grandgirard et al., Theory of Fusion Plasmas: Joint Varenna-Lausanne International Workshop, AIP Conference Proceedings – November 30, 2006 – Volume 871, pp. 100-111

[2] S. Jolliet et al., Theory of Fusion Plasmas: Joint Varenna-Lausanne International Workshop, AIP Conference Proceedings – November 30, 2006 – Volume 871, pp. 124-135