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Benchmarking of flux-driven full-F gyrokinetic simulations

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First-principles kinetic simulations are powerful tools to understand and predict plasma transport processes in magnetic confinement fusion devices. So far, a number of simulation studies have addressed the physical mechanisms involved in turbulent transport, and compared them with experimental results. In most cases, these codes tackle local transport phenomena under fixed plasma profiles. Since they compute the perturbed part of the distribution functions only, they are often called local delta-F gyrokinetic codes. Indeed, these codes have been well benchmarked and verified.

The assumption of the local approach may fail when the characteristic size of turbulence is non-negligible compared with the machine size or the profile formation is affected by plasma turbulence itself, possibly leading to an organization of meso-scale structures. To address these issues, a new generation of gyrokinetic codes called full-F have been developed, where the fluctuations and equilibrium profiles evolve self-consistently.

Contrary to the local delta-f gyrokinetic codes, there exist few benchmark works of full-F gyrokinetic codes. There are two reasons for this: enormous amount of computational costs for full-F codes and the complicated physics involved in these simulations.

In the talk, we first demonstrate the optimization strategies of these codes on the accelerators [1]. These optimizations will alleviate the computational costs of full-F codes. As a case study, we demonstrate how we applied the optimization strategies to GYSELA on Xeon Phi Knights Landing (KNL). Next, we present the details of benchmarks between GYSELA and GT5D. We mainly talk about the self-organized criticality (SOC) like behaviors of bursty transport, and profile formations.

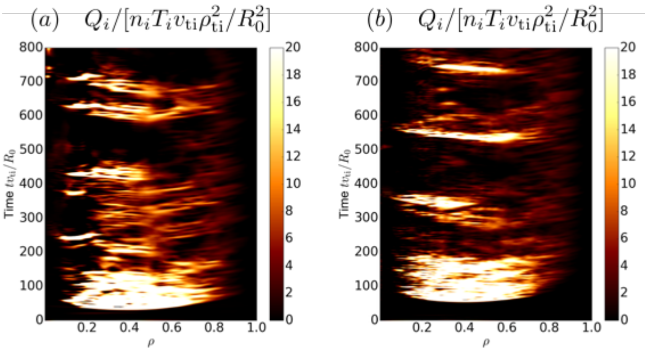

Figure 1. Spatio-temporal evolutions of the ion turbulent heat flux computed by (a) GYSELA and (b) GT5D.

Figure 1 shows the spatio-temporal evolutions of turbulent heat flux computed by GYSELA and GT5D. The avalanche-like transport is observed in both simulations. For quantitative comparison, the frequency spectra of turbulent ion heat flux is estimated. We report that 1/f type spectra and their transitions to $1/f^3$ type spectra are obtained in both codes in the flux-driven regime, by carefully setting the profile and heat source term. The quantitative agreement of the profiles is also demonstrated [2].

Finally, we show our on-going work focusing on the poloidal symmetry breaking, namely by poloidal convective cells, driven by turbulence as shown in Fig.2 . These cells are considered to affect the momentum and energy transport, both in the neoclassical and turbulence channels. We demonstrate the generation process of convective cells through turbulent Reynolds stress tensor. To understand the impact of convective cells on transport, we apply a numerical filter to convective cells and compare the results with and without the filter.

It is shown that the convective cells can impact the neoclassical transport, which can be interpreted as a synergy between turbulence and neoclassical dynamics.

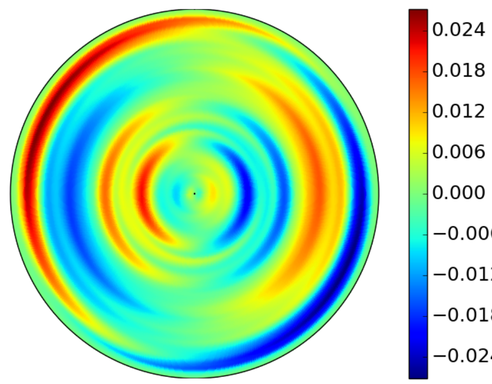

Figure 2. Poloidal cross-section of convective cells computed by GYSELA. This kind of structure breaks the poloidal asymmetry.

References

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