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Turbulence modeling and novel co-simulation of global transport dynamics

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The quantitative predictions and understanding of global turbulent transport and profile formation are crucial issues in fusion plasma study. In burning plasmas, one expects dynamic interactions of turbulent transport, profile formation, and spatiotemporal background variations such as heating and confining magnetic field. Variations in the pressure profile cause variations in the heating absorption and the magnetic geometry. However, such dynamic interactions have been ignored in conventional global turbulent transport simulations because of limited numerical models and computational costs.

A novel global turbulence-transport simulation, AGITO (Alterable Gyrokinetics–Integrated Transport cO–simulation), formerly called TRESS+GKV, which utilizes the simplified turbulent transport model [1] based on the nonlinear functional relation among turbulence intensity, zonal flow intensity, and turbulent heat diffusivity [2] is developed. Following earlier work [3], discretely distributed local gyrokinetic simulations are directly coupled with a 1–dimensional radial transport solver that calculates the time evolution of the pressure and plasma current profiles. The co-simulation is constructed using MPMD (Multiple Program Multiple Data) parallelization, where a well-behaved time evolution toward the power-balanced state is confirmed in the numerical verifications for the global ITG-driven turbulence simulation with stationary heating.

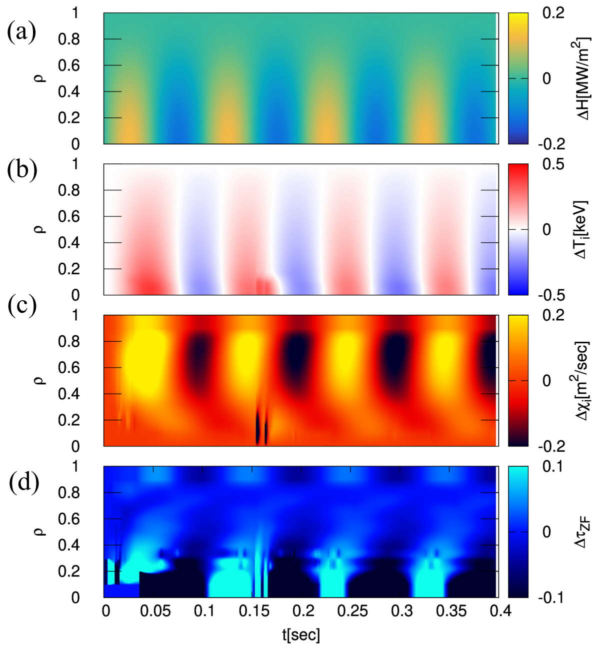

Figure 1. Each differential quantity of profiles due to heating modulation. (a)heating profile, (b)ion temperature, (c) turbulent diffusivity, (d)zonal flow decay time

AGITO has performed the impacts of heating power modulation and background magnetic field geometry modulation on global profile evolutions. In the case of heating power modulation (Fig. 1), we find different time-delay characteristics in the temperature, turbulent diffusivity, and zonal-flow intensity depending on the modulation frequency. Note that symbol Δ means a difference from the results of steady heating/magnetic field simulation. Then, to mimic the variation of the magnetic field geometry, only the metric tensor is modulated. Figure 2 shows the modulation frequency and difference quantity of ion temperature, turbulent diffusivity, and zonal flow decay time, respectively. Turbulent thermal diffusivity and ion temperature are shown to respond non-linearly to modulation of the magnetic field (metric tensor). The modulation of the metric tensor was shown to enhance zonal flow and increase the time-averaged ion temperature.

References

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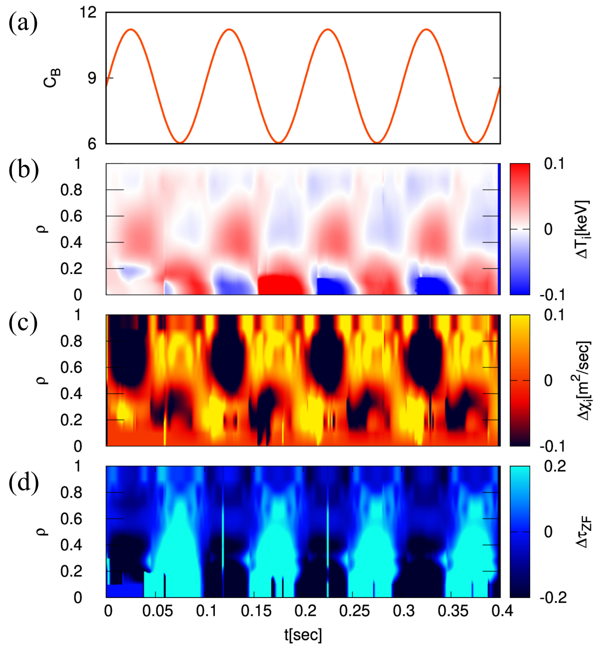

Figure 2. Each differential quantity of profiles due to magnetic field modulation (metric tensor). (a) modulation frequency, (b)ion temperature, (c) turbulent diffusivity, (d)zonal flow decay time