§46. Parallel Scheme for Multi-scale Plasma Simulations

Yagi, M. (Kyushu Univ.)

The suppression of plasma turbulence due to zonal flows plays an important role for anomalous transport[1]. However, the generation and collapse mechanism of the Internal Transport Barrier (ITB) is not well understood so far. It is necessary to investigate multi-scale dynamics to understand such nonlinear phenomena. In this research we have developed a global Ion Temperature Gradient driven drift wave (ITG) turbulence code to investigate the generation and collapse mechanism of ITB. The non-local interaction between turbulence and transport is identified by this simulation study[2]. The cylindrical coordinate system is used in the code, with the finite difference method applied to the radial direction and Fourier expansion applied to the azimuthal and axial directions. The heating and momentum sources are introduced to follow the profile evolutions and development of ITG turbulence. The linear part is solved implicitly and the nonlinear part is advanced by the predictor-corrector method. The nonlinear terms are evaluated in the Fourier space using the relation of three wave coupling which is the most expensive calculation in the code. A typical simulation needs about 10GB memory. The code is well optimized for vectorization and domain decomposition in the spectral space is applied so that parallelization using the message passing interface (MPI) library can be performed. It takes about one week to complete one run using four SX-8 CPUs. However, when a plasma turbulence well develops, the validity of the solution is limited by the Courant condition. If the time step becomes too large, then the simulation is manually restarted with Dt one magnitude smaller. Therefore, some experience is necessary to use the code well. To efficiently utilize the next generation super computer in NIFS, which will be introduced in the end of 2008 fiscal year, modification of the numerical and parallelization schemes should be done. Firstly, the FFTW (http://www.fftw.org/) library was installed on our PC cluster, then the pseudo-spectral code and the spectral code were benchmarked. It was found that if Fourier modes are greater that 512 modes, then the pseudo-spectral code is faster than the spectral code. So far, we have only tested a single version of FFTW. At the next step, we should compare the performance of the MPI and SMP versions of it. If the performance is good enough, then installation on SX-8 should be considered. Secondly, the singularity at the magnetic axis causes a numerical instability in the nonlinear regime. This often appears in the electromagnetic turbulence case. A numerical filter is introduced to smear out the singular behavior of eigen-functions near the magnetic axis, however this method does not work for the high beta case. Now, we are developing the Chebyshev expansion scheme[3] to replace the finite difference method in the radial direction. If this scheme works well, we will test the code on SX-8. Finally, there exists a multi-time step problem in the simulation. There are some solutions to resolve this problem. The full implicit scheme might be applied for nonlinear terms instead of the predictor-corrector scheme. This is one solution. Another possibility is to introduce a different time step for each mode and synchronized them periodically to evaluate the nonlinear terms. These methods should be tested in future work.

1) Diamond, P. et al. : Plasma Phys. Control. Fusion **47** (2005) R35.

2) Tokunaga, S. et al. : 11th IAEA TCM on H-mode Physics and Transport Barriers, Sep. 26-28, 2007, Tsukuba.

3) Trefethen, L.: Spectral Methods in MATLAB, SIAM 2000.