Towards understanding the role of turbulence on scaling of divertor heat flux profile widths on C-Mod and DIII-D

T.F.Tang[1,2], X.Q.Xu[2], B. Chen[3,2], C.H.Ma[4,2], T.Y.Xia[5,2], I. Joseph[2], B. LaBombard[6], J.W. Ahn[7], C. Lasnier[2], M. Makowski[2], and T.H. Osborne[8]

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[1]Dalian university of Technology, Dalian, China
[2]Lawrence Livermore National Laboratory, Livermore, California 94550, USA
[3]University of Science and Technology of China, Hefei, China
[4]Fusion Simulation Center, School of Physics, Peking University, Beijing, China
[5]Institute of Plasma Physics, Chinese Academy of Sciences, Hefei, China
[6]MIT Plasma Science and Fusion Center, Cambridge MA, USA.
[7]Princeton Plasma Physics Laboratory, Princeton, NJ, USA
[8]General Atomics, San Diego, CA 92186 USA,

To improve the understanding the role of edge turbulent transport on scaling of divertor heat load widths, BOUT++ code has been exploited. In support of the comparison with two experimental facilities, such as DIII-D and C-Mod, BOUT++ has been interfaced both with kinetic EFIT g-files for magnetic equilibria and p-files for experimentally measured plasma profiles.

We have used the BOUT++ electromagnetic Gyro-Landau-Fluid (GLF) module and 6-field two-fluid module to analyze the linear instabilities and nonlinear turbulent transport of three H-mode discharges from C-Mod and DIII-D. The BOUT++ code is employed to calculate the growth rates of a range of mode numbers (typically n~5-100) on each of these C-Mod and DIII-D discharges, and then switch on/off different physics models to identify the dominant free-energy sources for the instabilities, which are responsible to drive the turbulent transport. The DIII-D magnetic and plasma profiles are (1) stable for ideal peeling-ballooning modes for constant density profiles; (2) stable for electrostatic GLF simulations with adiabatic electrons, indicating that the DIII-D discharges are stable for electrostatic ITG modes with adiabatic electrons; (3) the most unstable mode peaks inside the magnetic separatrix near the position of peak ion temperature gradient and at the outside midplane, driven by the bad curvature. In addition, BOUT++ 6-field two-fluid module is also used for the linear calculations and the results are similar.

The nonlinear simulation results by BOUT++ 6-field two-fluid module show a qualitative agreement of turbulent heat flux onto outer divertor target with C-Mod. The simulated peak turbulent heat flux of C-mod is slightly smaller than the experimental measurements, while for DIII-D it is 3 times greater, possibly due to significant impurity radiation for the DIII-D detached plasma operation, which decreases the heat fluxes in front of the target. The simulated divertor heat flux profile widths are both narrower than experimental measurements.

In order to perform consistent scrape-off-layer plasma transport calculations, the 2D fluid code SOLPS has been externally coupled to the 3D turbulence code BOUT++ for DIII-D and C-Mod. The basis of this method is the use of file I/O transfer between the codes being coupled. The coupling procedure is described as follow. (1) BOUT++ turbulence simulations are first performed for DIII-D and C-Mod discharges to get saturated turbulent particle and heat fluxes using experimentally measured midplane plasma profiles inside separatrix; (2) Given plasma density and temperature almost at the separatrix as boundary conditions, and surface- and time-averaged turbulent fluxes in the SOL, the SOLPS simulations are performed to obtain a steady state SOL plasma profiles and heat fluxes at divertor plates. For coupled simulations, the radial profiles of turbulent transport coefficients have been calculated including the neoclassical transport and turbulent transport, results will be presented.

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