TH/5-2Rb: Theory and Gyro-fluid Simulations of Edge-Localized-Modes

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This paper reports the theoretical and simulation results of a gyro-Landau-fluid (GLF) extension of the BOUT++ code which contributes to increasing the physics understanding of edge-localized-modes (ELMs). Large ELMs with low-to-intermediate-n peeling-ballooning (P-B) modes are significantly suppressed due to finite Larmor radius (FLR) effects when the ion temperature increases. However, small ELMs with an island of instability at intermediate n values are driven unstable due to (1) the ion drift wave resonance with a branch of the drift acoustic wave in a two-fluid model and (2) the Landau wave–particle resonances with thermal passing ions in a gyro-fluid model. This result is good news for high ion temperatures in ITER due to the large stabilizing effects of FLR. The simulation results are shown to be consistent with the two-fluid model including the ion diamagnetic drift for type-I ELMs, which retains the first-order FLR correction. The maximum growth rate is inversely proportional to Ti because the FLR effect is proportional to Ti. The FLR effect is also proportional to toroidal mode number n, so for high n cases, the P-B mode is stabilized by FLR effects. Nonlinear gyro-fluid simulations show results that are similar to those from the two-fluid model, namely that the P-B modes trigger magnetic reconnection, which drives the collapse of the pedestal pressure. Hyper-resistivity is found to limit the radial spreading of ELMs by facilitating magnetic reconnection. Due to the additional FLR-corrected non-linear ExB convection of the ion gyro-center density, the gyro-fluid model further limits the radial spreading of ELMs. Zonal magnetic fields are shown to arise from an ELM event and finite beta drift-wave turbulence when electron inertia effects are included. These lead to current generation and self-consistent current transport as a result of ExB convection in the generalized Ohm's law. Because edge plasmas have significant spatial inhomogeneities and complicated boundary conditions, we have developed a fast non-Fourier method for the computation of Landau-fluid closure terms based on an accurate and tunable approximation. The accuracy and the fast computational scaling of the method have been demonstrated. This work supported in part by the US DOE under DE-AC52-07NA27344, LLNL LDRD project 12-ERD-022 and LDRD project 11-ERD-058. LLNL-ABS-527551.

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