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Simulations of Tokamak Boundary Plasma Turbulent Transport

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The BOUT++ code has been used to simulate edge plasma electromagnetic (EM) turbulent transport and to study the role of EM turbulence in setting the scrape-off layer (SOL) widths. More than a dozen tokamak discharges from C-Mod, DIII-D, EAST, ITER, and CFETR have been simulated with encouraging success. The simulation results reproduce the measured pedestal turbulence characteristics and the SOL widths. The principal results are: (1) the blobby turbulence originates in the pedestal peak pressure gradient region inside the magnetic separatrix and nonlinearly spreads across the separatrix. The electromagnetic fluctuations provide anomalous transport, which causes particle and heat to be turbulently transported radially down their gradients across the separatrix into the SOL. The electromagnetic fluctuations show the characteristics of both quasi-coherent-modes (QCMs) and broadband turbulence. (2) For simulations of C-Mod EDA H-mode plasmas, the mode spectra are in agreement with the phase contrast imaging data; radial location of the mode is generally consistent with measurements localizing QCMs to the pedestal/separatrix region. For simulations of EAST H-mode plasmas, the mode spectra are in agreement with the probe, interferometer, and POINT diagnostics. A series of simulations also shows that the edge bootstrap current plays a critical role to shift the most unstable mode to lower toroidal mode number, narrow the mode spectrum and enhance radial transport. Therefore, it is suggested to control the peeling modes and associated transport by introducing edge current drive to cancel bootstrap current, for example, by means of lower hybrid waves. This may lead to suppression/mitigation of type-I ELMs and facilitate access to the grassy ELM regime, thus opening a potentially new avenue for steady-state operations in ITER, CFETR and beyond.

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