Plasma turbulence simulations and experimental validation on the linear device LAPD*

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Results from 3-D fluid simulations of plasma turbulence are compared with experimental data from the Large Plasma Device (LAPD) at UCLA. LAPD is a magnetized plasma column with a high repetition rate, which allows obtaining detailed time-and-space resolved probe data on plasma turbulence and transport, and thorough comparison with the simulation results is possible due to large amount of data. For the observed drift-type modes, LAPD plasmas are strongly collisional ($\omega_*/\nu_{ei} \ll 1$ and $\lambda_{ei}/L \ll 1$), providing justification for a fluid treatment. Accordingly, the model is based on collisional plasma equations and implemented in the framework of the BOUT code, originally developed at LLNL for tokamak edge plasmas. Linear analysis of plasma instabilities indicates that resistive drift modes, Kelvin-Helmholtz modes, and rotation-driven interchange modes can all be important in LAPD and have comparable frequencies and growth rates. In nonlinear simulations, using measured LAPD density profiles, evolution of instabilities and self-generated zonal flows results in a saturated turbulent state. These simulations reveal good agreement with measurements in LAPD plasmas, in particular in the frequency spectrum, spatial correlation, and amplitude probability distribution function of density fluctuations. Turbulence spectra exhibit direct and inverse cascades in both azimuthal and axial wavenumbers and indicate coupling between the drift instability and Kelvin-Helmholtz mode. Moreover, consistent with the experiment, the simulations indicate a great deal of similarity between plasma turbulence in LAPD and some features of tokamak boundary turbulence. Similar to tokamak edge plasmas, density transport appears to be predominantly carried by large particle-flux events. Despite the intermittent character of the calculated turbulence, as indicated by fluctuation statistics, the turbulent particle flux is consistent with a diffusive model with diffusion coefficient close to the Bohm value.

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