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Saturation mechanisms in reduced simulations of boundary turbulence

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An important goal of turbulence research is the identification of the physical mechanisms that saturate linear instabilities in the tokamak edge region, as these dynamical processes serve as "control valves" in regulating strong-turbulent particle and energy transport from the edge into the scrape-off layer (SOL). Commonly identified saturation mechanisms include wave-breaking and zonal-flow shear stabilization.[1] We use our SOLT code[2] to simulate the turbulent evolution of vorticity, density, temperature and zonal fluid momentum, in the two dimensions orthogonal to the magnetic field in the outboard midplane region of a tokamak. In the simulation plane, the edge region supports the electron drift wave instability and curvature-driven instabilities, while sheath losses and the grad-Te instability are isolated in the SOL. Charge separation by the curvature and grad-B drifts enables blob transport[3,4] of density, temperature and vorticity (charge) from the edge into the SOL. A zonally-averaged momentum conservation law is used to advance the (bi-directional) zonal flow.[2] We artificially damp the zonal flow evolution to compete shear flow stabilization and wave-breaking. Absent this damping, the free evolution of zonal flow tends to minimize the particle flux into the SOL, the blobs are of the isolated "mushroom" variety, and the turbulence is intermittent. With increasing damping, and decreasing zonal-flow shear, particle flux into the SOL increases, and the blobs become quasi-periodic pulsating streamers. Exceptions to this scenario will be noted, e.g., as a function of sheath location.

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