Theory, Simulation, and Experimental Test of Turbulence Spreading

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Abstract

We study turbulence spreading corresponding to the spatio-temporal propagation of a patch of turbulence from a region where it is locally excited to a region of weaker excitation, or even local damping. A single model equation for the local turbulence intensity $I(x,t)$ includes the effects of local linear growth and damping, spatially local nonlinear coupling to dissipation and spatial scattering of turbulence energy induced by nonlinear coupling. In the absence of dissipation, the front propagation through the linearly unstable zone is ballistic with a charateristic speed given by a geometric mean of the linear growth rate and turbulent diffusion at nonlinear local saturation. The turbulence radial spreading into the linearly stable zone reduces the turbulent intensity in the linearly unstable zone, and introduces an additional dependence on the $\rho^* \equiv \rho_i/a$ to the turbulent intensity and the transport scaling. These are in broad, semi-quantitative agreements with a series of global gyrokinetic simulation results from GTC (gyrokinetic toroidal code). The front propagation stops when the radial flux of fluctuation energy from the linearly unstable region is balanced by local dissipation in the linearly stable region. The implications of these results on the inward spreading of edge turbulence toward the core and possible experimetal measurements are explored. It is found that transport in the edge-core transition region is significantly affected by the turbulence which is originated near the outer edge.