Experimental characterization of multiscale and multifield turbulence as a critical gradient threshold is surpassed in the DIII-D tokamak

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A critical gradient for long wavelength ($k_\theta \rho_s \lesssim 0.4$) electron temperature fluctuations has been observed in an experiment in the DIII-D tokamak [J.L Luxon, Nucl. Fusion **42**, 614 (2002)], where below a threshold value of $L_{T_e}^{-1} = |\nabla T_e|/T_e$ electron temperature fluctuations are constant and above they steadily increase. Above the critical gradient, the electron heat flux inferred by power balance also increases rapidly. Critical gradients are a predicted attribute of turbulence arising from linear instabilities and are thought to be related to transport stiffness. The presented results are the first direct, systematic demonstration of critical gradient behavior in turbulence measurements in a tokamak. The experiment was performed by changing the deposition location of electron cyclotron heating gyrotrons shot-to-shot to locally scan $L_{T_e}^{-1}$ at $r/a = 0.6$ in L-mode plasmas; rotation was also varied by changing the momentum input from neutral beam injection. Temperature fluctuations were measured with a correlation electron cyclotron emission (CECE) radiometry system. In addition to the CECE measurements, an array of turbulence measurements were acquired to characterize fluctuations in multiple fields and at multiple scales as $L_{T_e}^{-1}$ and rotation were modified: long wavelength ($k_\theta \rho_s \lesssim 0.5$) density fluctuations were acquired with beam emission spectroscopy, the phase angle between electron temperature and density fluctuations was measured by coupling the CECE system and a reflectometer, intermediate scale ($k_\theta \rho_s \sim 0.8$) density fluctuations were measured with a Doppler backscattering (DBS) system, and low frequency flows were also measured with DBS. The accumulated measurements and trends constrain identification of the instability responsible for the observed critical gradient to the ∇T_e-driven trapped electron mode.