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Core to Edge Variation of Multiscale Turbulent Transport in ITER Baseline Discharges at DIII-D[1]

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High fidelity gyrokinetic simulations and dedicated experiments that measured the heat and impurity transport from r/a = 0.5 to 0.9 in reactor relevant, ITER baseline discharges find compelling evidence of multi-scale turbulence. Ion-scale (ITG/TEM), electron-scale (ETG), and multiscale (coupled ion and electron-scale) simulations have been used to probe the radial variation of cross-scale coupling and its role in setting experimental levels of transport. Validation quality profile and fluctuation data (BES, DBS, PCI) were collected in conditions predicted to exhibit measurable characteristics of cross-scale coupling in intermediate scale density fluctuations ($k_\theta\ \rho_s \sim 3.0$). Over 70 nonlinear CGYRO simulations were performed to study ion and electron-scale turbulence and probe the sensitivity of results within experimental uncertainty at 5 radial locations. The simulations were compared directly with experimental heat transport levels, low and intermediate-k density fluctuations, and predicted trace impurity transport (D and V) across the profile. Simulated ion-scale turbulence reproduces experimental ion heat flux levels but under-predicts electron heat flux in many radial locations, pointing to a likely role of electron and multi-scale turbulence. To confirm the multiscale nature of the turbulence and validate the gyrokinetic model, cutting-edge simulation was performed at r/a = 0.7 on the Titan Supercomputer that spans ion and electron scales (up to $k_\theta\ \rho_s = 54.0$) with unprecedented physics fidelity (EM turbulence, realistic electron mass, rotation effects, collisions, all experimental inputs). The presented comparisons of ion, electron, and multi-scale simulation with experimental fluxes fluctuations reveal the physical mechanisms dictating radial variation of heat and particle transport in reactor-relevant conditions.

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