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Understanding pedestal transport through gyrokinetic and edge modeling[1]

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We report on a broad study combining the capabilities of gyrokinetic codes (GENE and CGYRO) and edge fluid codes (SOLPS and UEDGE) to identify the transport mechanisms active in pedestals spanning multiple devices (DIII-D, JET, C-Mod), modes of operation (H-mode, I-mode, QH-mode), fueling / heating levels, and wall materials. The gyrokinetic codes can analyze the instabilities and transport that arise in the pedestal while the edge codes provide the best possible estimate of particle sources. This study was carried out from perspective of the so-called transport 'fingerprint' conceptual framework, which compares basic physical signatures of prospective pedestal instabilities with the breadth of available experimental data, including frequency spectra, fluctuation scales and amplitudes, transport ratios, and inter-ELM profile evolution. Edge modeling determined that edge transport barriers typically lie in a regime in which heat diffusivity far exceeds particle diffusivity: $De/\chi e \ll 1$, which has major implications for the role of various pedestal instabilities. In conventional ELMy H-modes, microtearing modes and ETG turbulence dominate the electron heat transport; neoclassical dominates ion heat and impurity transport; and several candidates, including KBM, remain to explain the (small) particle transport. The presence of significant ion-scale electrostatic turbulence generally results in interesting variations on the standard H-mode pedestal theme. Detailed comparisons were carried out with experimental fluctuation data. Notably, simulations of microtearing modes quantitatively match distinctive frequency bands for multiple discharges on both JET and DIII-D. This study expands our understanding the transport mechanisms that determine many important properties of edge transport barriers and lays a foundation for predicting their behavior in future devices.

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