Full-f neoclassical simulations toward a predictive model for H-mode pedestal ion energy, particle and momentum transport

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Abstract. The role of neoclassical, anomalous and neutral transport to the overall H-mode pedestal and scrape-off layer (SOL) structure in an ELM-free QH-mode discharge on DIII-D is explored using XGC0, a 5D full-f multi-species particle-in-cell drift-kinetic solver with self-consistent neutral recycling and sheath potentials. Quantitative agreement between the flux-driven simulation and the experimental electron density, impurity density and orthogonal measurements of impurity temperature and flow profiles is achieved by adding random-walk particle diffusion to the guiding-center drift motion. This interpretative technique quantifies the role of the different transport mechanisms in establishing the total particle, energy and momentum transport through the pedestal and consequently illustrates the importance of including kinetic and neutral effects self-consistently in predictive transport calculations for the tokamak edge. The simulation indicates that energy and particle transport rates are decoupled in the H-mode edge since the ion thermal transport rate is primarily set by the neoclassical transport of the deuterium ions in the tail of the thermal energy distribution, while the net particle transport rate is set by anomalous transport of the colder bulk ions. Ion orbit loss and finite orbit width effects drive the energy distributions away from Maxwellian, and describes the anisotropy, poloidal asymmetry and local minimum near the separatrix observed in the T_i profile. The primary driver of the radial electric field (E_r) in the pedestal and SOL are kinetic neoclassical effects, such as ion orbit loss of tail ions and parallel electron loss to the divertor.

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