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Neoclassical Flows, Transport, and Non-Axisymmetric Effects in the Tokamak Plasma Edge[1]

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The drift-kinetic code NEO is used to explore the neoclassical transport and flows for parameters relevant in the plasma edge. NEO includes multiple ion species, general geometry, strong rotation effects, and full-linearized Fokker-Planck collisions. Comparisons are made with measurements of the deuterium and carbon flows for DIII-D L-mode discharges. An assessment of the accuracy of analytic models for the bootstrap current finds that NEO provides a 15% correction to the Sauter model for experimental plasmas. Analysis of the recent XGC0-based modification by Koh et al., finds that while the Koh modification is negligible for typical DIII-D plasmas, there is a large discrepancy from the NEO results in the pedestal for NSTX plasmas due to a failure in the formula at large inverse aspect ratio for large collision frequency ($\nu_{*_e} \sim 1$), and thus the Koh formula is not accurate in regions where it differs from the Sauter model. Overall, the resulting implication that NEO could significantly improve the accuracy of peeling ballooning and kinetic ballooning mode stability calculations in the edge barrier region is explored through coupling with the EPED model. Finally, NEO is extended to include toroidal non-axisymmetric effects for studies of magnetic field ripple and resonant magnetic perturbations. The equilibrium is generated using a new 3D local analytic equilibrium solver, analogous to a 3D extension of the Miller formalism for shaped axisymmetric equilibria, based on the formalism by Hegna. Unlike a global solver, the method allows for systematic studies of the effects of 3D flux-surface shaping parameters. With the solver, the onset of stochasticity for general 3D flux surface configurations is studied. Combined with NEO, the effects of enhanced neoclassical transport due to the formation of superbanana orbits and the development of a more accurate kinetic-based NTV are explored.

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