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Simulation of 3D effects on partially detached divertor conditions in NSTX and Alcator C-Mod

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Establishing a validated, predictive capability for the divertor plasma is critical for future fusion reactors, which must operate with detached divertors to reduce peak heat fluxes to the plasma facing components (PFC) and to mitigate net material erosion. This is challenging even for existing 2D codes, and is complicated further by non-axisymmetric effects due to divertor-localized gas injection, 3D magnetic fields, and 3D PFCs, modeling of which requires 3D simulations. New experiments performed on C-Mod at the request of the ITER organization to examine the consequence of localized nitrogen gas injection, show clear toroidal asymmetries in radiated power, impurity radiation, and divertor pressure. The 3D plasma/neutral transport code EMC3-EIRENE has been applied to model these experiments in the first attempt to benchmark the code against tokamak experimental data under detached conditions. The measured pressure modulation and the impurity radiation trends in the edge are qualitatively reproduced by the simulations, which also predict a $\sim$ 2x modulation in heat flux at the outer strike point. Discrepancies are found in comparison with the measured private region radiation, and the simulations also indicate colder, denser divertor conditions than measured, suggesting that drifts and kinetic corrections may be required for more quantitative agreement. In separate experiments on NSTX, detached divertor plasmas are observed to reattach when 3D fields are applied. Modeling of the NSTX experiments reproduces these trends, with an increased peak heat flux with 3D fields and qualitative agreement of the striated flux patterns. The experimental identification of toroidal asymmetries in detached plasmas highlights the need for reliable 3D models for projecting the impact for ITER and beyond. Support from USDOE DE-AC05-00OR22725, DE-AC02-09CH11466, DE-FC02-99ER54512.