Efficient Implicit Coupling of Fluid-Plasma and Monte-Carlo-Neutral Models for Edge Plasma Transport*

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An accurate coupled treatment of fluid-plasma and kinetic-neutrals models of the tokamak edge and scrape-off layer is necessary for the interpretation and prediction of divertor performance in present and future tokamaks [1]. We report on investigations of various approaches to the efficient implicit coupling of such models.

While a highly efficient implicitly coupled combination of *fluid*-neutrals and plasma models exists within the UEDGE code [2], a kinetic [e.g. Monte-Carlo (MC)] treatment of the neutrals is necessary in some important regimes. Existing couplings of these with plasma-species models are explicit [3], often making them very slow computationally due to numerical "stiffness" associated with the large disparity between the fast (e.g., charge-exchange and ionization) and slow (transport/global equilibration) time scales.

The approaches investigated are based upon Newton's method, and include quasi-Newton (e.g., generalized Broyden's methods and Anderson mixing) and Jacobian-free Newton-Krylov methods (e.g., GMRES).

In our case the constituent codes are the plasma component of UEDGE and the DEGAS-2 MC-neutrals code [4]. For algorithm testing, we use a Cartesian box geometry and plasma conditions based on previous studies [3]. Additional insight is gained through comparison with and analysis of simplified model systems consisting of either two coupled fluid fields diffusing in one dimension or of one fluid field coupled to a MC species, with controllable sources and coupling terms.

Key issues addressed include the development of adequate robust "preconditioners," necessary for the Newton-like methods to converge rapidly, and optimization of the convergence of the calculation and of the accuracy of the resulting solution with respect to the MC "noise."

*Prepared for US DOE by LLNL under Contract DE-AC52-07NA27344 and LDRD project 15-ERD-059, and by PPPL under Contract DE-AC02-09CH11466. The contributions to this work by PPPL were supported by the U.S. DOE, Office of Science, Fusion Energy Sciences.

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