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Direct multi-scale coupling of a transport code to gyrokinetic turbulence codes, with comparisons to tokamak experiments

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To faithfully simulate ITER and other modern fusion devices, one must resolve electron and ion fluctuation scales in a five-dimensional phase space and time. Simultaneously, one must account for the interaction of this turbulence with the slow evolution of the large-scale plasma profiles. Because of the enormous range of scales involved and the high dimensionality of the problem, resolved first-principles simulations of the full core volume over the confinement time are very challenging using conventional (brute force) techniques. In order to address this problem, we have developed a new approach in which turbulence calculations from multiple gyrokinetic flux tube simulations are coupled together using gyrokinetic transport equations to obtain self-consistent equilibrium profiles and corresponding turbulent fluxes. This multi-scale approach is embodied in a new code, Trinity, which is capable of evolving equilibrium profiles for multiple species, including electromagnetic effects and realistic magnetic geometry, at a fraction of the cost of conventional direct numerical simulations. Key components in the cost reduction are the extreme parallelism enabled by the use of coupled flux tubes and the use of a nonlinear implicit algorithm to take large time steps when evolving the equilibrium. In this talk, we describe the multi-scale model employed in Trinity and present simulation results using nonlinear fluxes calculated with the gyrokinetic turbulence codes GS2 and GENE. We compare the numerical predictions from Trinity simulations with experimental results from a number of fusion devices, including JET and MAST.