Direct multi-scale coupling of a plasma transport code to gyrokinetic turbulence codes, with comparison to fusion experiments.

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To faithfully simulate modern fusion devices, one must resolve electron and ion Larmor scale fluctuations 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 techniques. In order to address this problem, a new approach has been developed 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 presentation, the multi-scale model employed in `TRINITY` is described and simulation results using nonlinear fluxes calculated with the gyrokinetic turbulence codes `GS2` and `GENE` are presented. Numerical predictions from `TRINITY` simulations are compared with experimental results from a number of fusion devices, including JET and ASDEX Upgrade. Also presented are results from numerical studies of the self-consistent interaction between equilibrium flow shear and turbulence.