Developing Experimentally Relevant Benchmarks for Gyrokinetic Microstability Codes

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A few nonlinear gyrokinetic microstability codes are now capable of simulating tokamak plasmas to an unprecedented level of complexity. These codes include plasma shaping, trapped electrons, multiple kinetic impurities, interspecies collisions, magnetic fluctuations, and most recently, equilibrium E_r. Verification of these "experimentally relevant" simulations is difficult, however, because no benchmarks exist with which the codes can compare. This work describes the development of such benchmarks through "apples-to-apples" comparisons among codes. The assumption is that the results are correct if all the codes agree, i.e., it is highly unlikely that all the codes would give identical erroneous results. Apples-to-apples here means not only solving for the same plasma but also including the same physics and having sufficient temporal, spatial, pitch-angle, and energy resolutions. The procedure is as follows: One utility code is used to extract experimental data from analysis by TRANSP, ONETWO, etc., and to produce input files for all the codes. A single input-file generator is desirable to ensure the code inputs are identical. The codes are first run linearly and, if differences in the mode frequencies are found, the computations are simplified by removing shaping, collisions, etc. until agreement is reached. These are replaced, one at a time, until differences reappear, thereby pinpointing the source(s) of the disagreement. The code developers then resolve the disagreement. This process is repeated with increasing levels of complexity. Then nonlinear runs are undertaken for the same cases and the procedure is repeated. The final result will be benchmarks, both linear and nonlinear, at various levels of complexity which other codes should be able to reproduce to be considered verified. The entire process could be repeated for different plasma conditions, thereby creating additional benchmarks. Because this verification procedure is performed using experimental data, it yields the bonus of simultaneously being a validation exercise for the participating codes.