Testing of edge gyrokinetic/gyrofluid codes on NSTX-U data

Greg Hammett, Ammar H. Hakim, PPPL

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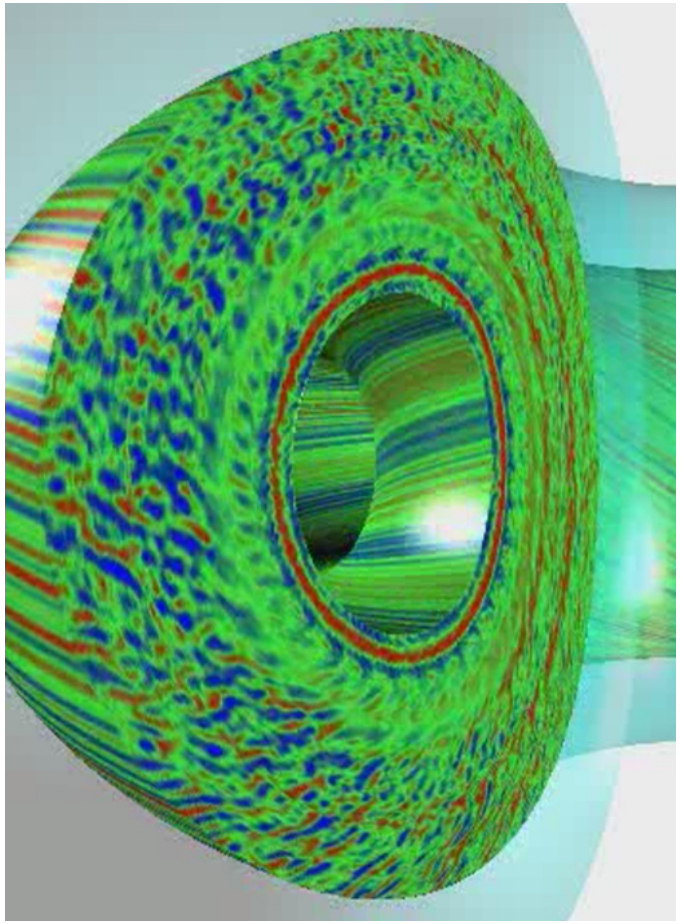
NSTX Theory and Computation Brainstorming Workshop



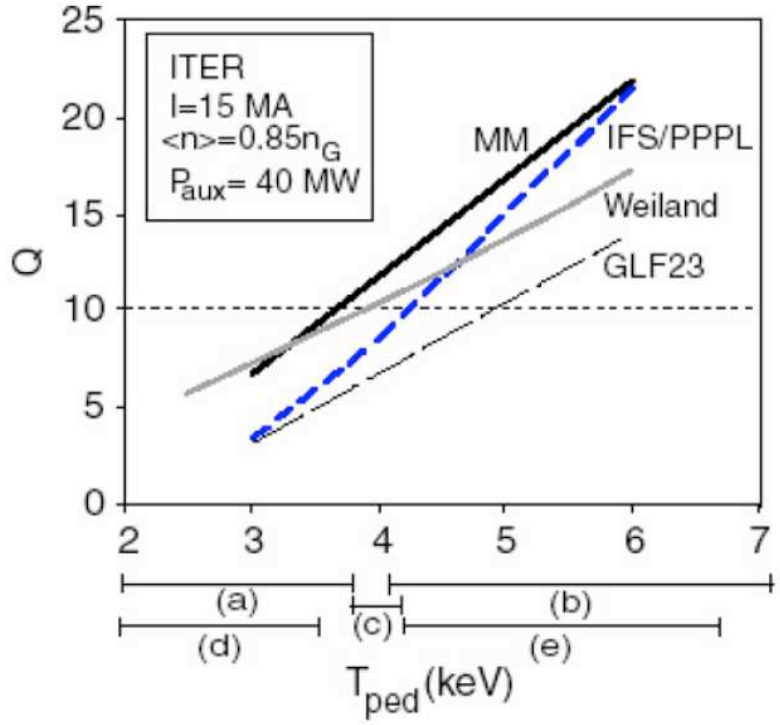
GYRO simulation, Candy & Waltz 2006

Codes like GYRO and GENE provide comprehensive simulations of core plasma turbulence, but major extensions needed to handle additional complications of edge region:

> open & closed field lines, steep gradients near beta limit, electric and magnetic fluctuations, strong shear-flow layers, large amplitude fluctuations, non-axisymmetric RMP coils, plasma-wall interactions, strong sources and sinks in atomic physics.

Various groups working on gyrokinetic & improved gyrofluid codes for the plasma edge region. Hopefully these codes will be ready for extensive testing against experiments during 2014-18. General testing of these codes should be a significant part of NSTX-U 5-year plan. What diagnostics will be most useful?

Performance of Tokamak Fusion Power Plants (like ITER) Depends Sensitively on Edge Physics



Predicted fusion gain Q from core transport models vs. assumed temperature at top of pedestal (T_{ped})

Fig. 5, "Progress in ITER Physics Basis", Nucl. Fus. 2007, http://www.iop.org/EJ/abstract/0029-5515/47/6/S01

Exploratory project studying advanced algorithms for edge gyrokinetic turbulence

We (Hakim & Hammett) are developing a prototype edge gyrokinetic code to explore the usefulness of certain advanced algorithms for difficult edge problem.

Factor of 2 reduction in resolution requirements in each of 5D+time gives 64x speedup.

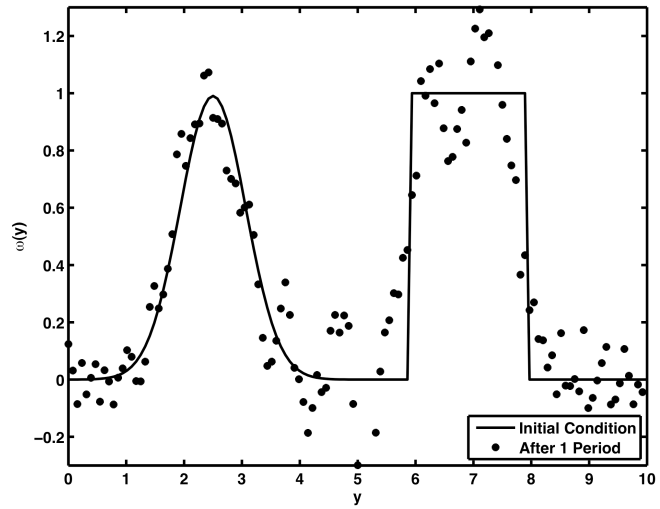
In particular: variations of a hybrid Discontinuous Galerkin (DG) method
(DG a hot topic in applied math & CFD in past decade):

> DG appears to combine low phase errors and high efficiency of spectral elements, with robustness & speed of shock-capturing finite-volume methods. Efficient limiters to prevent negative densities in sharp gradients of edge region. Parallelizes well & handles complex geometries well. Hopefully: a code that can run robustly on a coarse grid (with subgrid models) with fluid-like speeds, while having the option to crank up resolution.

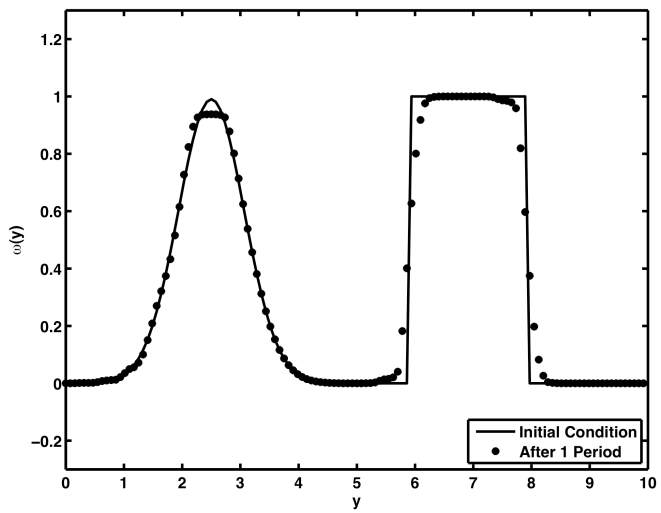
Goal: A prototype 5-D edge turbulence code in 2-3 years (with simplified models of some physics). Decide whether algorithms worth implementing in other codes, and whether to continue development of prototype code.

Recent advances in limiters avoid clipping

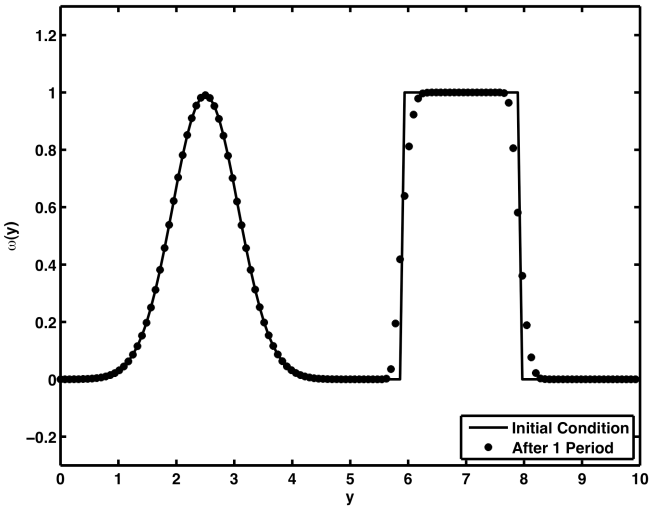
Arakawa Algorithm



Standard PPM4



New XPPM



- Simple 1D advection test: $\partial f/\partial t + v\, \partial f/\partial x = 0$ solution (points) should overlay initial condition (line)
- Recent advances in limiters for Finite-Volume interpolations (Colella-Sekora 08, Suresh-Hyunh 97) eliminates clipping at smooth extrema (being used in Edge Simulation Laboratory code). Think this can be extended to DG while preserving certain useful properties.
- Important in edge plasma to avoid negative density overshoots.

Peterson Hammett (2012)