Validation - an experimentalist’s perspective

G.R. Tynan

UCSD

Goal of the Exercise:

Show that a class of simulations reproduces the essential turbulent transport physics across a wide range of experiments, operating conditions, and devices

Use those simulations to provide insight into the future performance of new experiments
Hierarchy of Approaches & Requirements:

- **Lowest level**: Effective transport rates (fluxes or transport coefficients)
- **Intermediate level**: Turbulence & mesoscale structure statistics (spectra, corr functions, amplitudes, cross-phases, ZF/GAM amps, frequencies)
- **Deeper level**: Nonlinear dynamics of the turbulence/mesoscale system

Increasing Diagnostic Complexity & Analysis
Hierarchy Also Extends Across Devices, Conditions, and Models

- **Collisionless/weakly collisional finite beta plasmas:**
  - Core of tokamaks, stellarators;
  - GK Simulations

- **Collisional plasmas w/ finite beta**
  - Edge region;
  - collisional GK simulations, fluid simulations

- **Highly collisional plasmas w/ low beta**
  - Separatrix/SOL; small confinement devices & lab plasmas
  - collisional GK simulations, fluid simulations
An Example: Zonal Flow Generation from Collisional Drift Turbulence in a Lab Plasma

Tynan et al April 2006 PPCF
Comparing G.K. simulations with turbulence data: Current approach based on fluid picture of plasma

**Simulation results:**
\[ \tilde{f}_{i,e}(\bar{x}, \bar{v}, t) \]

**Reduced results:**
\[ \int \tilde{f}(\bar{x}, \bar{v}, t) d\bar{v}, \int \tilde{\nu}f(\bar{x}, \bar{v}, t) d\bar{v},... \]

**Synthetic diagnostic**
reproduces spatio-temporal response of turbulence diagnostics

**Data analysis tools for**
experiment and virtual data
(spectra, corr functions, PDFs, etc…)

UCSD
New Synthetic Diagnostic Capability Allows Direct Comparisons of Simulated and Measured Turbulence Characteristics

- Synthetic BES and CECE diagnostics have been developed as IDL post-processing tools for use with GYRO simulations.

- Short term goal is to develop corresponding IDL interface for GTC which will use same tools.
Application to Particle-based GK Simulations (e.g. GTC,...)

- Turbulence Analysis Requires Ensemble Averaging to Obtain Meaningful Result
- Experiments Use Ergodic Thm (Time Average = Ensemble Average)
- Simulation run time is short (~msec currently)
- Particle based approach MUST quantify significance of noise which will limit simulation duration
- **Impact:** Use spatial sampling of statistically independent regions; **may also need to consider ensembles of runs**
Status of Validation in this Project

- Several core plasma virtual diagnostics already exist (BES, CECE, PCI) or could be developed (Reflectometry, Scattering)
- Results have been integrated with DIII-D Turbulence Analysis Tools
- Need to develop interface between GTC Codes and Virtual Diagnostics
- Need to develop mesh generation from experimental configurations for input to GTC
- NEED TO RECRUIT A POST-DOC (UNDERWAY)
Likely Future Directions

• Consider how to integrate wave-particle physics into this process (going beyond fluid picture)
• Integrate into collisional edge/SOL GK simulations & cross-compare against fluid edge/SOL simulations
  – Would enable cross-model and small expt/confinement expt cross-comparisons
• Link core & edge/SOL simulations