TTF 2011
Session: Consider oral, (F) Verification & Validation WG

Ensemble-Based Validation Metrics for Turbulent Transport Modeling*

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Meaningful model validation requires using quantitative metrics for assessing the fidelity of the model(s) under consideration to experiment. Ideally, the metrics used to assess a given model should incorporate tests of predictions against experimental measurements at multiple levels of the "primacy hierarchy" [1], and incorporate both experimental and model uncertainties in the evaluation of model fidelity. In this work, we propose a suite of validation metrics for assessing the fidelity of microturbulence-based transport predictions, which incorporate both model and experiment uncertainty quantification into their assessments via the use of ensemble statistics. The fundamental approach is to first use ensembles of equilibrium profile fits (constrained by experimental uncertainties) to quantify uncertainty in power balance flux calculations. These correlated ensembles can then be used to generate ensembles of "fixed-gradient" turbulent flux predictions, or "flux-matching" transport solution profiles, for a given microturbulence model. For each transport channel, a pair of simple metrics based upon the ensemble average of the reduced χ^2 error measures of the equilibrium profile and associated flux is identified. A composite metric for assessing "net" fidelity in each transport channel is also identified, based upon the ensemble average of a geometric mean of the individual profile and flux simple metrics. This approach allows for simple and direct quantification of relative and absolute model fidelity over the entire plasma volume, or selected subregions, and an easy graphical presentation via use of radar plots. It is also easily and directly extensible to incorporate tests of predicted local fluctuation characteristics such as amplitudes, correlation lengths, and crossphases. Finally, it allows the definition of a validation "vocabulary," by providing a clear way of associating statements such as "poor" or "very good" agreement with quantifiable levels of model fidelity. Examples of the toolset as applied to TGLF and GYRO modeling of DIII-D discharges are provided.

[1] P.W. Terry *et al*., Phys. Plasmas **15** (2008) 062503.

*Work supported in part by the U.S. Department of Energy under DE-FG02-07ER54917, DE-FG02-08ER54984 and DE-FC02-04ER54698.