SENSITIVITY OF CORE TRANSPORT PREDICTION TO THE SEPARATRIX TEMPERATURE AND DENSITY IN TOKAMAK L-MODE AND OHMIC REGIMES

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Simulation of the core temperature of L-mode DIII-D discharges with the TGLF-SAT2 transport model has been shown to be accurate with a boundary condition taken from experiment within 98% of the separatrix [1]. Prediction of L-modes temperature and density, without using measured profiles, has also been demonstrated in ASDEX-Upgrade using a 2-point models for the separatrix temperature boundary condition [2] and a separatrix density chosen to be 1/3 the line average density. The unknown core particle source from recycling was adjusted to match the line average density. Here we will explore sensitivity of the core transport prediction to the separatrix boundary condition by simulating a set of DIII-D discharges. The core transport simulations are provided by the IPS-FASTRAN integrated modeling framework [3]. A simple linear surrogate model of the core recycling source as a function of the separatrix density is fit to IPS-FASTRAN simulations. The role of the resistive ballooning mode in the fueling efficiency is explored comparing a local threshold condition derived by Scott [4] evaluated in the center of the zone of neutral source from near the separatrix.

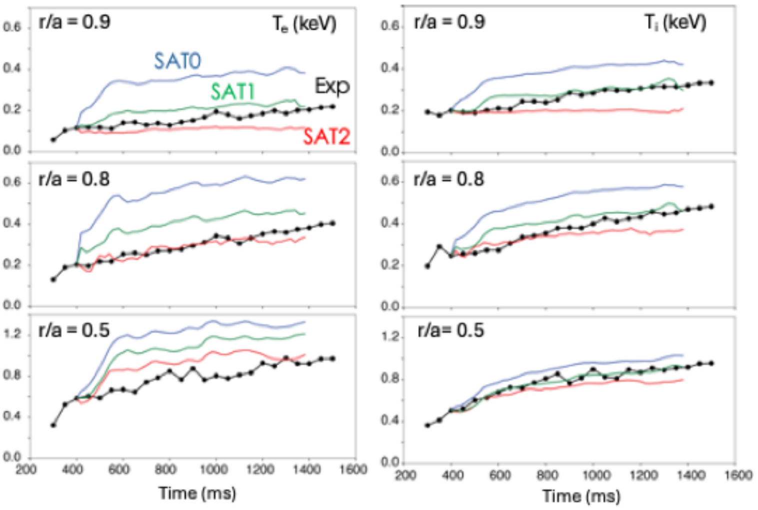

Fig. 1 IPS-FASTRAN simulation of a DIII-D current ramp discharge with three different TGLF saturation models: SAT0, SAT1, SAT2 and the measured experimental electron (left) and ion (right) temperatures (Exp) at three radial locations (r/a=0.9 top, 0.8 middle, 0.5 bottom) (reproduced Fig. 2 from Ref. 1) .

The results of a time dependent simulation of an ITER-similarity current ramp-up experiment on DIII-D with TGLF [5] is presented in Fig. 1. The original saturation model for

TGLF (SAT0) [6] overpredicts the temperatures with a stronger gradient near the separatrix than measured for this Ohmic plasma. This has also been widely observed in L-mode [1]. This transport shortfall prevents TGLF-SAT0 from being useful for predicting the current ramp-up and L-mode phases of ITER for scenario modeling because it predicts an internal inductance of the plasma that is too low. The newer saturation models (SAT1 [7], SAT2 [8]) include the multi-scale zonal flow coupling to electron temperature gradient (ETG) instabilities. These models were calibrated to multi-scale gyrokinetic turbulence simulations of a C-MOD L-mode [9] with GYRO [10]. The SAT2 model has a more accurate dependence on the flux surface shape that was fit to fully spectral gyrokinetic simulations with CGYRO [11].

The SAT2 model has been shown to predict the global energy confinement of AUG L-modes better than the ITER-89P empirical scaling [2]. The separatrix boundary temperature was computed with a 2-point model of the scrape-off layer (SOL) and the separatrix density was taken to be 1/3 of the target line average density. The separatrix neutral density (particle source) was adjusted to match the line average density target of the AUG discharges. This demonstration of the ability to predict the L-mode energy confinement better than empirical scaling is significant progress. In principle, the separatrix plasma temperature and density and neutral density could be computed with a SOL transport model like SOLPS [12]. However, a validated theory-based model of the cross-filed transport in the SOL due to turbulence is not available, so the SOLPS calculations are not predictions. As a preliminary study we have tested the sensitivity of the core prediction of DIII-D L-modes with IPS-FASTRAN to the boundary conditions for electron and neutral density.

The same set of DIII-D L-modes used in the validation test of TGLF reported in Ref. 1is used for the sensitivity test. The line average density (nebar) vs the separatrix density (nesep) for this database is shown in Fig. 2 (blue dots). The relations nebar = 3 nesep (red dots) used for the AUG predictions and nebar = 1.8 nesep (green dots), which will be shown to be a zero source lower bound, are also shown in Fig.1. The low density cases are close to the red dots but the line average density falls below this line at higher density. The difference between the blue and green dots must be made up by particle sources.

The results of a large number of IPS-FASTRAN runs are shown in Fig. 3. Every dot is a separate IPS-FASTRAN run for the same discharge (090752) evolving Te, Ti and Ne to equilibrium with TGLF-SAT0 and NCLASS [13]. The separatrix temperature is taken from experiment. The slope of the line average density with