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B2-Eirene (SOLPS) Modelling of JET SOL plasma flow

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I. Introduction

The scrape-off layer (SOL) of tokamak plasmas is home to strong plasma flows, which are still relatively poorly understood. Recent Mach probe measurements, at the top of the poloidal cross-section [1], have suggested their existence in JET. The radial profile of the measured parallel flow Mach number, $M_{||}$, rises from $M_{||} \sim 0.2$ in the separatrix vicinity to a peak of $M_{||} \sim 0.5$ in the near SOL for forward toroidal field (FWD-B) operation (i.e. with the ion $\mathbf{B}\times\nabla B$ drift directed downwards and where positive flow corresponds to the direction from outer to inner divertor targets). In reversed field (REV-B), the flow is observed to be more stagnant throughout the SOL except near the separatrix, where the flow increases again to reach the forward field value in both magnitude and direction (see e.g. Fig. 6 in Ref. [1]).

Modelling efforts using the EDGE2D/NIMBUS coupled fluid-Monte-Carlo neutral code and including drift effects have failed to reproduce the SOL flow magnitude and have only qualitatively matched the profile shape [1]. We report here on equivalent efforts using the alternative code package SOLPS5.0 (B2.5-EIRENE). This activity complements the ongoing benchmarking exercise between the above two codes [2,3]. To avoid the added complexity of high recycling near the targets, plasma discharges with low density, attached divertor plasma conditions were selected for the simulations. In common with the EDGE2D code runs, both impurities and SOL drifts were included, with the same set of experimentally obtained SOL and divertor plasma profiles being used to constrain both the SOLPS5 and EGDE2D simulations. Each code contains a self-consistent treatment of the neutral dynamics, albeit using different Monte-Carlo neutral packages. The radial transport

* See the Appendix of J. Pamela *et al.*, Fusion Energy 2004 (Proc. 20th Int. Conf. Vilamoura, 2004) IAEA, Vienna (2004).

coefficients and other run parameters providing the best match to the experiment are compared between the codes.

II. Modelling parameters

The EDGE2D modelling has been described in detail elsewhere [1]. For the SOLPS5 exercise, we have attempted to use the same set of input parameters as for the EDGE2D runs, whenever possible and justified by the data. In both FWD-B and REV-B cases, a heating power of Pcore = 1.6 MW (split into P_e = 1.0 and P_i = 0.6 MW) and n_e^{sep} = 0.6×10^{19} m^{-3}, are found to yield an approximate best match to the divertor target profiles of T_e and n_e (see Figures 1 and 2). The EDGE2D simulations used transport coefficients profiles for D_i beginning with a value of 0.5 m^2/s at the separatrix, increasing to 1.5 m^2/s about 2 cm into the SOL, and then returning to 0.5 m^2/s. For the SOLPS runs, the same initial behaviour is retained, but the transport coefficients do not return to the separatrix value, but rather continue to increase in the far SOL, reaching a value of 5.0 m^2/s. This provided a marginal improvement of the fit to the experimental data for the SOLPS runs compared to using the original EDGE2D transport coefficient profiles. In both codes, we assume $\chi_e = \chi_i = 2\ D_i$. The transport coefficients are also given a ballooning-like character, with a 1/B variation. The effect of the latter is found to be rather small in SOLPS5. At higher ballooning factors, i.e. powers of B variations, the Mach number profiles are seen to shift together towards higher positive values, but the difference between forward and reversed cases remains roughly constant [4]. The transport coefficients in the private flux region are scaled down by a factor of 4 in SOLPS5 with respect to their separatrix values. The SOLPS5 runs also make use of heat flux limits with a 0.15 coefficient for both ions and electrons, while EDGE2D has flux limits turned off. Both codes have been run with their drifts terms turned on in the SOL, as well as in the outer part of the core for SOLPS5.

III. Results

Figures 1 and 2 compare respectively the measured and simulated target profiles for the FWD-B and REV-B cases. These are used to constrain the simulation parameters. The agreement between both codes and the experiment is satisfactory, but not perfect. In particular, the inner target temperature profiles agree between both codes (FWD-B), but are much lower than experiment. In REV-B, a better agreement is found between EDGE2D and the data than with SOLPS5. At the outer target (REV-B), the chosen case is a balance between SOLPS5 matching the density and temperature profiles. An almost perfect match of the density profile can be achieved with SOLPS at a slightly higher density (namely n_e^{sep}

$= 0.8\times10^{19}$ m^{-3}), but at the cost of a temperature profile much too low over the entire SOL radial width. The private flux region density profiles are also better matched with SOLPS5, (in which the transport coefficient rescaling by a factor of 1/4 has been used in that region), than with EDGE2D.

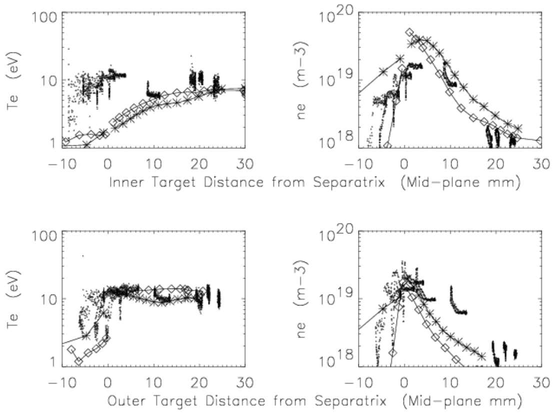

Figure 1. Inner (top) and outer (bottom) target T_e (left) and n_e (right) profiles as measured by the Langmuir probes (points), simulated by EDGE2D (stars) and by SOLPS5 (diamonds) for shot number 56725, FWD-B.

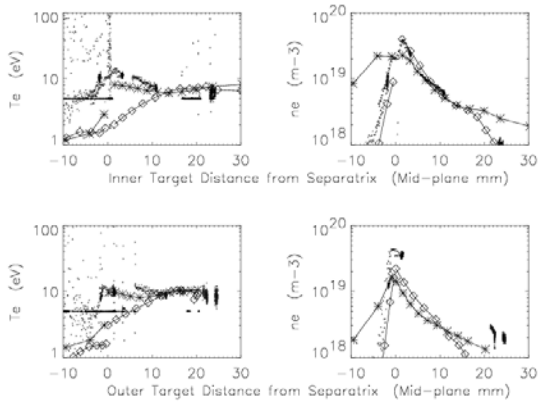

Figure 2. Inner (top) and outer (bottom) target T_e (left) and n_e (right) profiles as measured by the Langmuir probes (points), simulated by EDGE2D (stars) and by SOLPS5 (diamonds) for shot number 59733, REV-B.

In contrast, and this is a key result of this benchmarking exercise, in neither case (SOLPS5 or EDGE2D) can the simulations match the high values of $M_{||}$ measured at the top of the machine by the fast scanning reciprocating Langmuir probe (RCP) for FWD-B (Figure 3). In fact, although the codes do obtain the right direction for the flow in addition to prediction a roughly constant magnitude throughout the SOL, this magnitude is almost a factor 5 (for SOLPS5) and 10 (for EDGE2D) too small. The situation for the REV-B cases is different. Good agreement is found between experiment and theory in the case of SOLPS5, but EDGE2D again fails to match the measured flow magnitude or direction. However, because of the much worse agreement in FWD-B, this also means that neither the average flow across both field directions (experimentally $M_{||}^{ave} \sim 0.2 - 0.3$), nor the difference between them ($\Delta M_{||} \sim 0.7 - 0.8$) can be matched by either code. The maximum difference in Mach number ΔM_{max} between the two field directions is of order 0.8 in experiment, 0.3 in SOLPS5, and only 0.1 in EDGE2D. The same physics model is being used for both sets of simulations, and the fact that it agrees (in the SOLPS5 case) with experimental results in REV-B but fails to reproduce the magnitude of the FWD-B flows, the average value and the difference between field directions is indicative of missing ingredients in the physics model.

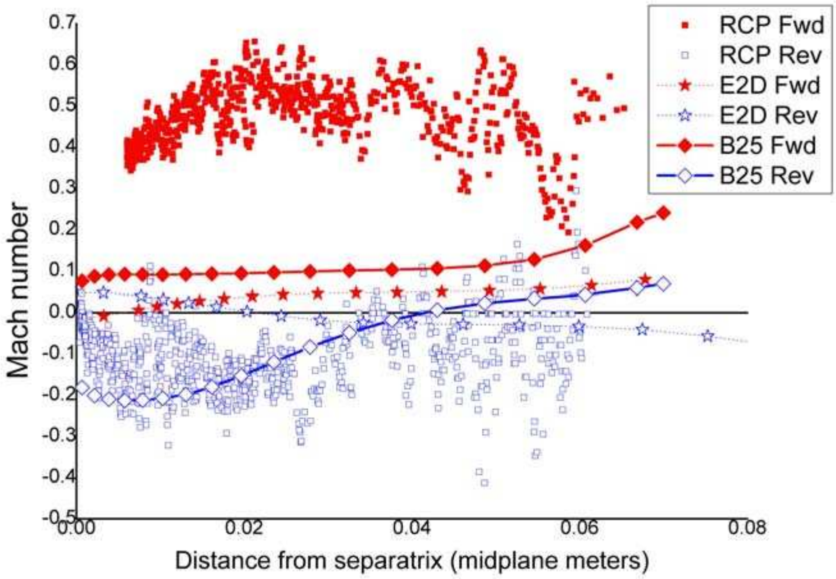

Figure 3. Comparison of Mach number profiles from RCP data (RCP: points), EDGE2D (E2D: stars) and SOLPS5 (B25: diamonds) simulations. FWD-B: filled symbols, REV-B: hollow symbols.

IV. Conclusions

A pair of matched low-density JET discharges have been modelled with both the EDGE2D and the SOLPS5 fluid SOL plasma simulation codes. This effort complements an ongoing benchmark exercise between EDGE2D and SOLPS5. The results from both codes, although matching quite well the inner and outer density and temperature target profiles, do not satisfactorily reproduce the Mach number profiles measured at the top, low field side of the machine by means of a fast scanning reciprocating probe. In FWD-B, both codes yield flows which are much too small in magnitude, but in the right direction. In REV-B, SOLPS5 obtains a rather good match, but it remains unclear at this time whether this is fortuitous or indicates that there is missing ingredient in the physics model for FWD-B cases with drifts.

V. References

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