Plasma edge simulations including realistic wall geometry with SOLPS-ITER

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The SOLPS-ITER [1,2] code suite is presently the most widely used package for plasma edge modeling in the magnetic fusion community. It interprets exhaust scenarios in most existing devices, and supports the design of future devices, such as ITER [3], DEMO, or CFETR. One of the important limitations of the package is the restriction of the simulated plasma domain to outer magnetic flux surfaces contacting divertor targets at both ends. This prohibits an accurate assessment of particle and heat loads to the other plasma-facing components such as the main chamber wall.

We present here a newly developed numerical solver for the B2.5 plasma code, allowing the numerical grid to be extended to the true vessel boundaries. The scheme generalizes the extended grids capability developed originally for the B2 code [4] and carried over into B2.5 (SOLPS5.0-ITM) [5]. The new, unstructured Finite Volume scheme can deal with arbitrary grid and magnetic topologies in the 2D poloidal plane. It includes a correct numerical treatment of possibly misaligned cells w.r.t. the magnetic field to cope with, for example, strong divertor target shaping [6]. As such, the solver combines the benefits of an accurate numerical separation of fast parallel and slow radial transport, with a realistic description of the wall geometry, and the possibility of local grid refinement to capture sharp features in the scrape-off layer (SOL) flows. We present generalized sheath boundary conditions that can now be imposed at all vessel boundaries, removing an important modeling uncertainty related to the specification of ad-hoc decay length boundary conditions at the outer flux surfaces.

The resulting model is applied to representative test cases in single-null, double-null and limiter configurations. We analyze in particular the impact of the extended plasma model on far SOL flows, and main wall particle and heat loads. Moreover, we assess the improved description of fluid neutral transport in the divertor which is enabled by the adapted solver. Fluid neutrals are restricted to the plasma grid, implying that important features such as direct transport of (fluid) neutrals between inner and outer divertor through the near-vacuum private flux region could not be captured by the original solver. The extended solver allows for a much improved qualitative agreement between fluid and kinetic neutral simulations.