Comparison of kinetic and fluid models for neutral atoms in the plasma edge of ITER

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SOLPS-ITER is a multi-physics mean-field code suite used for simulating the plasma edge of tokamaks [1]. Traditionally, it employs a fluid approach for the plasma combined with a Monte Carlo simulation for the kinetic neutral particles. In the charge-exchange dominated regimes, as expected in ITER and future fusion reactors, the strong ion-neutral collisionality justifies the use of a fluid description for the neutrals. This led to the development of advanced fluid neutral models by N. Horsten et al. [2]. Such models have been incorporated in SOLPS-ITER by M. Blommaert et al [3] and W. Van Uytven et al [4].

Until now, these fluid neutral models have only been tested in simplified orthogonal geometries. This is because SOLPS-ITER typically employs a 5-point stencil which implicitly assumes orthogonal grids. However, the target plates of most tokamaks are not orthogonal to the magnetic field. As a consequence severely distorted numerical grids are used. Using the 5-point stencil for the isotropic neutral transport therefore leads to poor agreement between fluid and kinetic neutral models. Recently, the SOLPS-ITER code suite has been redeveloped to accommodate a fully unstructured solver including consistent 9-point stencil discretization to account for non-orthogonal grids [5].

We have incorporated the aforementioned fluid neutral models in the unstructured SOLPS-ITER code. Fluid-kinetic discrepancies on the plasma particle and momentum sources of only 10-15% have been achieved for a partially detached D-only ITER case, paving the way towards an order of magnitude speed-up for ITER-relevant plasma edge simulations. We perform a density scan to analyse in detail the validity range of the fluid neutral approach. The increased consistency of these fluid neutral models with the kinetic models [2] allows to more clearly separate true kinetic behaviour from model discrepancies, providing detailed insight in the applicability of fluid neutral models in plasma edge simulations.