Impact of tungsten charge state bundling on scrape-off layer transport simulations in JET L-mode plasmas

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The tungsten ion average charge states in EDGE2D-EIRENE simulations of the JET scrape-off layer are predicted to decrease by up to 40% when the 74 ion states are bundled into 6 fluid stages, compared to reference cases using the Monte Carlo code DIVIMP and a more elaborate bundling scheme in EDGE2D-EIRENE. The ionization state has a major impact on the W force balance in the SOL and thereby also on the accumulation of W in the core plasma. W radiation cools down the core plasma such that W concentration much above $10^{-5}$ causes intolerable loss of performance in a fusion reactor [1]. Comparison of W transport code predictions in computationally more accessible L-mode plasmas allows the identification of potential ways to improve prediction accuracy of the core W content using edge fluid codes.

The studied simulations are L-mode plasmas [2] with deuterium as the main species and beryllium and tungsten as intrinsic impurities. The main source of tungsten in the EDGE2D-EIRENE cases is sputtering due to beryllium ions at the HFS divertor and charge-exchange deuterium neutrals at the LFS divertor [3]. The simulations are validated against experiment using divertor spectroscopy of neutral and singly ionized tungsten emission lines.

EDGE2D-EIRENE simulations with tungsten ion stages for charges 1, 2-6, 7-12, 13-22, 23-73 and 74 predict the same tungsten charge profile as DIVIMP in the core region, but the average charge states in the SOL tend to be approximately 30% lower in EDGE2D-EIRENE than in DIVIMP. This results in the core W concentration in DIVIMP exceeding EDGE2D-EIRENE predictions by around 50%. When the bundling scheme in EDGE2D-EIRENE is changed to include each individual charge up to 20+, all charge states residing in the SOL, the predicted charge states match those predicted with DIVIMP in all regions.

Earlier assessments of the impurity bundling scheme in EDGE2D-EIRENE found only a weaker bundling effect of order 10% on W core leakage when injecting tungsten at the LFS mid-plane [4]. The usage of large amounts of ionization stages greatly increases computation time and lowers code stability. Therefore, the Monte Carlo approach or bundling schemes prioritizing charge states 1-15 may be considered.