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The role of statistical noise in edge plasma transport codes based on kinetic Monte Carlo solvers for neutrals: an analogy with turbulent fluctuations

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Power exhaust is one of the major challenges that future devices such as ITER and DEMO will face. Because of the lack of identified scaling parameters, predictions for divertor plasma conditions in these devices have to rely on detailed modeling. Most plasma edge simulations carried out so far rely on transport codes, which consist of a fluid code for the plasma coupled to a kinetic Monte Carlo (MC) code for neutral particles (atoms, molecules). An example of such tools is the Soledge2D-EIRENE code developed in our team. One of the main difficulties in interpreting code results is the lack of a proper convergence criterion for the simulations, because of the statistical noise originating in the kinetic MC calculation. Here, we take a new look at these noise related issues. We argue that these two problems share strong similarities, and that what is usually referred to as the steady state reached by a transport code after convergence bears strong resemblance with the statistically stationary state (SSS) reached by a turbulence code. We argue, by analogy with turbulence related studies, that the proper choice for the solution of coupled fluid-kinetic Monte Carlo simulations is the time average of the SSS. In most of the cases, this quantity is time independent, and is solution of a well-defined set of equations. The latter exhibits additional terms compared to the initial system, originating from its parametric and/or statistical non-linearities. The additional terms can be calculated from the SSS, and provide a physical picture of the effects of the noise. Numerical results show that if the spatial structure of the noise is frozen long enough for the plasma to adjust, then the mean solution can differ markedly from the noise free solution. We present cases for which noise leads to a lower recycling divertor. Nevertheless, the mean particle balance is satisfied even in those cases, highlighting the need to monitor the effects of noise closely, because usual sanity checks on the solution might not fail even in cases where the solution is strongly affected. The relative importance of the various noise-induced terms is discussed, in order to explain the mechanisms through which noise can push the mean solution towards less recycling conditions, at least in the simulations presented here.

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