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Impact of poloidal convective cells on transport processes with kinetic electrons

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Recently, a lot of attentions have been paid to the role of poloidal asymmetries of electrostatic potential in magnetic confined plasmas. It is known that poloidal asymmetries of the $E \times B$ plasma flow are instrumental in neoclassical transport. Nevertheless, this kind of structures are often neglected in standard neoclassical theory, since the amplitude of poloidal asymmetries is expected to be small according to standard neoclassical theory. There are however, several situations where poloidal asymmetries cannot be negligible. For instance, a centrifugal force due to toroidal rotation and RF heating of minor impurities can generate poloidal asymmetries. Even without them, plasma turbulence which is intrinsic in fusion plasmas, can drive flows that are not poloidally symmetric, due to their ballooned feature. These poloidally non-symmetric structures are called poloidal convective cells herein.
Although there are some experimental evidences that poloidal convective cells could have significant impacts on transport processes, particularly on impurity transports, further theoretical studies are needed for understanding complicated transport processes. In order to investigate the impact of poloidal asymmetries on the transport processes, we have introduced a new hybrid kinetic electron model in full-F global gyrokinetic code GT5D [Y. Idomura et al, Comput. Phys. Commun. 179, 391-403 (2008)]. Contrary to the original hybrid electron model in GT5D [Y. Idomura, J. Comput. Phys. 313, 511-31 (2016)] where convective cells are filtered out, the new hybrid electron model keeps convective cells with a new assumption in the passing electron dynamics. If the convective cells interact with both neoclassical and turbulence dynamics, this may be the most reliable approach, since full-F global gyrokinetic code can model neoclassical and turbulence transport processes consistently.
In order to verify the new model, we carry out neoclassical simulations and zonal flow damping tests using both original and new hybrid electron models. We show that the particle flux induced by magnetic drift is enhanced with the presence of convective cells and the frequency and damping rate of zonal flows are changed following the theoretical estimate in the new model. Finally, we compare the flux-driven simulation results with both hybrid electron models. It is shown that the particle, momentum and energy transport driven by magnetic drift are enhanced with the presence of convective cells, while they tend to be cancelled by their counterparts induced by $E \times B$ drift of convective cells. This behavior agrees with our previous work [Y. Asahi et al, PPCF 61, 065015 (2019)] qualitatively. As shown in our previous work, the impact of convective cells on equilibrium profiles are quite limited even with kinetic electrons.

Country or International Organization

Japan

Primary author: Dr ASAHI, YUUICHI (QST)

Co-authors: IDOMURA, Yasuhiro (Japan Atomic Energy Agency); YAGI, Masatoshi (National Institutes for Quantum and Radiological Science and Technology, Rokkasho Fusion Institute)

Presenter: Dr ASAHI, YUUICHI (QST)

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