Non local features of flux driven gyrokinetic simulations

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Both experimental measurements and numerical simulations show that turbulent transport in tokamak plasmas may exhibit non-local features, in the sense that the local flux does not depend only on the local gradient. Understanding the underlying physical processes and quantifying the consequences in terms of transport remains a matter of active research. The present work emphasizes some of these critical issues which recently emerged in flux driven gyrokinetic simulations using the GYSELA code. Implications on experimental measurements are also discussed.

First of all, the critical mismatch between gradient-driven and flux-driven approaches is highlighted. By providing a self-consistent dynamics of the gradient around its mean value, the latter approach leads to a rich exploration of the dynamics of the system. Given some prescribed reduced transport model, such as the generic critical gradient model, it will be shown that the computed flux depends critically on the underlying statistical properties of the fluctuations of the gradient, and on the distance to the threshold. This toy model which captures some of the reported gyrokinetic results, questions the prediction efficiency of gradient-driven models and calls for refined experimental measurements.

Secondly, non-local features can be attributed to the interaction between small-scale turbulence and large-scale structures, mediated by propagating or stationary waves. It is long known that turbulence itself can generate such large-scale structures. Zonal Flows are the most emblematic ones. More recently, large axi-symmetric turbulence-driven convective cells have also been identified, characterized by low poloidal wave numbers (m=1,2) of the electric potential. These compete with – or add up to – those emerging from neoclassical physics as a result of vertical charge separation. Both physics are possibly related to the experimentally reported poloidal asymmetries of the flow in several tokamaks. GYSELA simulations where convective cells are artificially suppressed allow one to quantify their impact on transport. The total momentum transport appears to be weakly affected in the core. Conversely, they are found to significantly contribute to heat transport. Also, their strong impact on density poloidal asymmetries likely governs the reported synergy between turbulent and neoclassical transport of impurities, as recently suggested. Further evidence of such a synergy on impurity transport will be discussed, emphasizing the additional role of the centrifugal force. Finally, the conditions for the onset and sustainment of these turbulence-driven m=1 cells have been clarified and will be exposed. It turns out that Landau damping is small at low frequency, so that the amplitude of quasi-steady cells is mainly dictated by shielding polarization effects.