Departure from Maxwellian distribution and algorithm determining weights of fluid closure terms

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Fusion plasmas are low collisional and highly turbulent. It is acknowledged that kinetic equations are needed to describe accurately such systems, in particular wave-particle interactions. Nevertheless, when discussing the physics of the turbulence, at best fluid moments are considered, and quite often a single effective diffusion coefficient is reported. This is sharply in contrast with the large amount of computer resources required to achieve these results. It also underlines the eased insight into the physics at hand that is provided by the fluid description of turbulent plasmas.

We analyze the GYSELA gyrokinetic simulations with ITG turbulence, adiabatic electrons in the flux driven regime, hence without scale separation, neither in physical space, hence in global geometry, nor in velocity space, hence with a full-f code. Our first goal is to quantify the departure from Maxwellian distributions in the non-linear regime of turbulent transport. When averaged on flux surfaces, one finds that the distribution function is close to a Maxwellian, while local values on a flux surface appear to depart significantly from such a Maxwellian. In order to quantify this departure, we addressed the issue of the reference Maxwellian distribution function. The initial equilibrium distribution function being discarded because of the large departure from that state, one can consider the distribution characterized by the same three first moments. However, the relative error at high velocities proves to be quite difficult to handle when quantifying the distance between these distributions. The alternative is to consider the tail of the distribution taking into account the adiabatic response at high velocities. With such a procedure the non-Maxwellian character is essentially contained in the thermal part of the distribution function and alternative tools to Hermite and Laguerre projections are needed. Using the reduced model for trapped particles, we investigate Trapped Ion Mode turbulence, for bounce averaged trajectories. The TERESA code, sister code to GYSELA, has been developed to perform kinetic simulation in 3D, the kinetic energy and conjugate space coordinates. This model allows one investigating the precision requirements introduced by the discretized Hermite and Laguerre projections, as well as precise distribution function dynamics depending on the turbulent transport regime achieved in the simulation.

Along this analysis of the kinetic signature of turbulent transport associated to micro-convection and ballistic transport at the meso-scale, we also investigate means to determine effective closures of the hierarchy of projections when reducing the problem to moments depending on real space coordinates only. We have tested in a fluid code the possibility of recovering with a specific algorithm the coefficients weighing the different terms of the underlying equation. These are obtained with a good precision, in spite of the disparity of values, using the structure in space and time of the solution. These results will be presented together with the first results when considering the TERESA kinetic model. Means of determining appropriate closures with such an algorithm will also be addressed.