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# Zonal Flows and GAMs in Comparative Gyrokinetic and Two-Fluid Tokamak Turbulence Simulations

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Fluid turbulence simulations cannot describe the kinetic effects due to the scarcity of collisions in tokamak plasmas but allow for much higher spatial resolution than kinetic simulations and become more reliable at large collision frequencies. Conversely, gyrokinetic simulations, the standard in current tokamak turbulence modeling, cannot be performed with the full set of nonlinearities that become relevant at the edge region of tokamaks, due to the high fluctuation amplitude. In addition the high collision numbers at the edge make gyrokinetic simulations numerically and physically challenging.

To allow a more reliable operation of both approaches in their respective fringe regions of validity and applicability, and to isolate special kinetic effects from the more robust fluid physics, results on ZF and geodesic acoustic modes (GAM) obtained with the non-local two-fluid Braginskii code NLET have been compared with gyrokinetic code simulations. The specific study of the global flows is of particular interest, with a view towards an eventual understanding of the L/H transition and the associated edge flows.

An important cave-at raised by the comparisons is that particular care has to be taken with the physics and numerics of the collision operator used in the gyrokinetic codes, so that the proper fluid limit is eventually reached for high collisionalities. On the other hand, the gyrokinetic results can guide the proper renormalization of the fluid dissipative terms to account for the kinetic damping mechanisms (Landau-damping and phase-mixing) to prevent a partial break-down of the fluid description at the lower collisionalities.

The regions of validity and renormalizations of the fluid and gyrokinetic codes outlined by the present paper can be used to study regions close to the edge, where the gyrokinetic ordering breaks down, such as near the L/H transition or the density limit, and are a valuable sanity check for both
approaches. Lastly, the presented results improve the understanding of the physics when kinetic phenomena can be reproduced in first principle fluid codes.

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