Gyrofluid simulation on the nonlinear excitation and radial structure of GAMs in ITG turbulence

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Geodesic Acoustic mode (GAM) is a class of toroidal mode with finite low frequency. It is characterized in spatial structure by poloidally and toroidally symmetric potential and poloidally asymmetric density or pressure fluctuations. The latter gives rise to a time-dependent zonal flow in toroidal plasmas. GAM dynamics is important to turbulence transport studies since their low-frequency radial structure can modulate or scatter drift-wave fluctuations, which are primarily responsible for collisionless transports. GAMs can be generated nonlinearly similar to the stationary zonal flows in turbulence. In this work, we mainly study the nonlinear excitation processes and the radial structure of GAMs in tokamak plasmas by using newly well-benchmarked local and global gyrofluid codes. At first, a closure relation for gyrofluid modeling is presented for zonal flows and ion temperature gradient (ITG) fluctuations. The zonal flow damping is precisely benchmarked in these gyrofluid codes by comparing with theoretical predictions and other kinetic calculations. Then, the codes are applied to simulate the nonlinear generation of GAMs by ITG fluctuations, which can be approximately estimated through a parametric analysis of three-wave coupling. We found that in low safety factor q plasmas, the stationary zonal flow is driven nonlinearly accompanying with weak GAM components. Whereas, robust GAMs are excited nonlinearly in high q plasmas due to the weak ion sound wave dynamics. The stationary zonal flow is reduced through the balance with the time-dependent proportion and the collisionless Landau damping of GAMs. The nonlinear excitation mechanism of GAMs is discussed. Further, the radial mode structure of GAMs is investigated in the system of zonal flows, ion sound wave and GAMs by performing global toroidal ITG simulation. The radial spectrum of GAMs is identified and the radial propagation in inhomogeneous temperature plasmas is addressed.