Anomalous Bootstrap Current and Poloidal Flow Generation and Global Turbulent Transport in Tokamaks and STs

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New insights obtained from gyrokinetic studies of fusion experiments regarding underlying mechanisms for driving anomalous poloidal flow observed in DIII-D, the influence of microturbulence on bootstrap current generation and multiple-channel plasma transport in STs are reported. Nonlinear, global gyrokinetic simulations employed in these studies include both turbulent and neoclassical physics self-consistently. i) ITG turbulence, while producing experimentally relevant heat transport, is found to drive a significant poloidal Reynolds stress in the core region of DIII-D, where significant anomalous poloidal flow is observed. The divergence of the Reynolds stress produces a proper torque in the right direction, which, by balance with the neoclassical viscous damping, offers a source needed for driving the observed anomalous poloidal flow. The weak dependence of ITG-generated Reynolds stress profile on ion collisionality due to time scale separation between turbulence and collisional zonal flow damping in low collisionality regime suggests that the observed collisionality scaling of anomalous poloidal flow may result from the neoclassical viscous damping. The CTEM fluctuation-induced torque from simulations of a C-MOD L-mode plasma is show to switch direction due to the change of mode propagation from ion to electron diamagnetic direction, suggesting poloidal flow is modified differently than in ITG regime. ii) Global gyrokinetic simulations including both turbulent and neoclassical physics self-consistently show that bootstrap current generation is significantly enhanced in the presence of CTEM turbulence due to electron flow generation by turbulent residual stress and acceleration, consistent with results of turbulence-only-simulations. The CTEM driven current is essentially carried by trapped electrons, associated with their drift center dynamics. A significant modification of bootstrap current is predicted for a CTEM-dominated C-MOD L-mode core plasma. iii) Large toroidal rotation generally characterizing in ST experiments, on one hand, is found to drive shear flow instability in NSTX L-mode plasmas. On the other hand, the strong rotation gradient creates a strong $\mathbf{E} \times \mathbf{B}$ shear which is shown to largely suppress low-k fluctuations and associated transport both linearly and nonlinearly. The remaining finite low-k fluctuations contributed by both ITG and shear flow mode can produce a significant ion thermal transport relevant to experimental level in the outer core region. Low-k fluctuations in L-modes may also produce a significant anti-gradient residual stress along with momentum pinch and diffusion. Low-k electrostatic turbulence, however, is shown to play little role in NSTX H-mode plasmas mostly due to strong-shaping-induced increase in gradient threshold for instabilities.