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Limit Cycle Oscillations and L/H Transitions from Two Dimensional Mean Field Momentum Transport Equations

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The two dimensional momentum transport of the mean field (i.e. low frequency compared to the turbulence) ExB toroidal and ion poloidal velocities are modeled with both collisional and turbulent contributions to the transport equations. The radial and temporal evolution of the edge barrier is modeled. It will be shown that there are both normal one-step L/H transitions to suppressed turbulence and newly discovered limit cycle oscillations, from this two dimensional system, without the aid of oscillations from turbulent zonal flows. The results of the new model will be compared with recent high resolution measurements of L/H transitions and limit cycle oscillations, or dithering transitions, which have given unprecedented detail of the dynamics and spatial structure of the plasma velocities and turbulence. The properties that govern which type of transition occurs in the 2-D momentum equations are the collisional poloidal velocity damping force and the Reynolds force (radial derivative of the Reynolds stress). Over a range of ExB velocity shear, the effective momentum diffusivity due to the turbulence is negative, which provides the drive for the instability. The linear stability of the two dimensional momentum equations admits purely growing and finite frequency instabilities. Non-linear gyro-kinetic turbulence simulations are shown to have a zonal electric field energy that is a fraction of the total electric field energy of the turbulence as the mean field ExB velocity shear is increased. The L-mode is a state of high turbulence and zonal electric field energy and the H-mode has suppressed turbulence and zonal flow electric field energy. The new momentum transport modeling has a low mean field ExB velocity in the L-mode and a poloidal velocity that departs from the neoclassical value due to the high momentum transport driven by the turbulence. In the H-mode barrier region, the modeling gives mean field ExB and ion poloidal velocities that approach neoclassical levels. These properties compare well with the measured radial structure of the L- and H-mode plasmas.

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