# Modelling Transport Bifurcations in the CSDX Linear Device

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The CSDX machine is a cylindrical magnetized helicon plasma device where collisional plasma is created by injection of external gas from one end and confined by means of a constant axial magnetic field. Recent experiments performed on CSDX showed that when the magnetic field value exceeds a critical threshold $B_{cr}$=1200G, a global transition in the plasma profiles occurs, as indicated by the formation of a strong ExB shear flow layer and the steepening of the density gradient. Moreover, performing a forward/backward scan of the magnetic field near values close to $B_{cr}$ revealed the existence of a hysteresis loop in the density gradient modulus and an increase in the normalized shearing criterion $|v'_{ExB}\tau_c|$ to values greater than unity for $B>B_{cr}$ (here $v'_{ExB}$ is the radial derivative of the drift velocity and $\tau_c$ is the turbulent fluctuation correlation time). More interestingly, a radially localized net inward, up-gradient turbulent particle flux directed toward the center of the plasma was observed and studied experimentally in [1-2]. The observations also suggest that during this transport bifurcation, a change in the nature of the turbulence features occurs from simply being pure drift waves to becoming a mix of drift waves and ITGs at the same time.

In this work we explore these experimental results using a simple 1D numerical transport model employing a gradient dependent mixing length. The mixing length is a nonlinear one, related to the Rhines scale of the turbulence and not to the linear instability scale as usual [3]. The Rhines scale is $\nabla n$ and $\nabla u$ dependent (here u is the fluid vorticity), and shrinks as $\nabla n$ and $\nabla u$ steepen. The model is simple because it is purely diffusive for $n$ and $u$, and does not include any flow pinch expression. The particle and the vorticity flux expressions are taken to be plasma density and plasma vorticity gradient dependent. Note that here Reynolds force enters via the diffusion of vorticity (i.e. PV mixing).

The model is a 3-field Hasegawa–Wakatani based mesoscale model. It describes the space and time evolution of the mean plasma density $<n>$, the mean plasma vorticity $<u>=<\nabla^2\varphi>$ and the turbulent potential enstrophy $e$. This simple diffusive model probes the dynamics of turbulent particle transport and self consistently describes turbulence suppression in the CSDX device. As the Reynolds work increases, the work done by turbulence on the flow increases and so does the flow shear. This steepens the plasma density profiles, leading to further suppression of turbulence. In our simulations, we adopt mixed boundary conditions; Dirichlet conditions at the outer edge of the plasma and Neumann conditions at inner edge of the plasma cylinder. Additionally we report the results of simulations performed with and without the presence of external density sources and sinks that result from additional ionization of injected neutrals. Simulation results clearly show a steepening in the particle density profile along with the development of a region of a net inward radial particle flux. The formation of a net flow shear layer resulting from the vorticity mixing process is also evident, even in the absence of any explicit particle sources. These results suggest the existence of a system dynamic capable of sustaining the plasma core by means of a diffusive particle flux, without any explicit inward particle pinch. Further comparisons of the model with experimental results are ongoing and will be discussed.

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This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Fusion Energy Sciences, under Award Numbers DE-FG02-04ER54738 and DE-SC0008378.