# Fluid Description, Equations For Pedestal Transport Modeling*

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*Background.* Plasma transport processes in the hot core of tokamaks are usually modeled (e.g., in ONETWO, TRANSP, ASTRA) using a one-dimensional (1D) plasma description which assumes that most plasma properties (e.g., $n_e$, $T_e$) are constant on magnetic flux surfaces, and the sources (e.g., due to NBI) and sinks are flux-surface-averaged. Also, kinetic descriptions are needed to describe the fluid moment closure relations and micro-turbulence-driven anomalous plasma transport. In contrast, on and outside the divertor separatrix a two-dimensional (2D, and perhaps even 3D) description is required, and usually collisional Braginskii closure relations and fluid moment descriptions are employed (e.g., in UEDGE, and SOLPS). The edge pedestal in H-mode plasmas exists between these two regions. In order to model plasma transport properties in the pedestal region the key questions are thus: 1) To what degree are 2D processes critical?, 2) How can the most important such processes be modeled?, and 3) What are approriate fluid moment descriptions for this plasma region?

*2D Processes.* Very near and on the magnetic separatrix a number of physical processes become 2D. For electrons $T_e$ is well equilibrated along field lines down to about 75 eV, which is about the electron temperature on the separatrix, at least in DIII-D. However, the neutral source is clearly 2D on and just inside the separatrix — in to $\rho \lesssim 0.95$? Also, electron and impurity densities, and the potential might have 2D character up to about where $T_e \gtrsim$ 300 eV? Further, ion orbit losses become important within a poloidal ion gyroradius of the separatrix.

*Near Separatrix Geometry.* Straight field line coordinates for $\mathbf{B} \equiv \boldsymbol{\nabla}\psi \times \boldsymbol{\nabla}[q(\psi)\theta - \zeta]$ are convenient in neoclassical, paleoclassical and microturbulence studies of kinetic processes in hot tokamak plasmas. And a 1D description is obtained by averaging over flux surfaces. The same $\psi, \theta, \zeta$ coordinates or more general axisymmetric coordinates can be used in the near-separatrix pedestal region; however, axisymmetry in the $\zeta$ direction needs to be utilized and the 2D $(\psi, \theta)$ properties retained — i.e., one should not flux surface average.

*Fluid Moment Description.* Plasmas in the pedestal are usually not in a collisional, Braginskii regime, except possibly very close to the separatrix where $T_e \lesssim 100$ eV. Thus, over most of the pedestal the closures for fluid moment equations need to allow for low collisionality (plateau and banana) regimes. Such kinetic-based closures can be obtained [1] via a Chapman-Enskog-type approach. Also, Pfirsch-Schlüter flows and $n_e, \Phi$ variations within a flux surface are important in 2D decsriptions. Finally, it seems that [2] toroidal flow evolution needs to be treated on an equal basis with the $n_e, T_e$ etc. transport in the pedestal.

*Pedestal Transport Model.* In this work we begin developing a pedestal plasma transport model that allows for: 1) 2D processes, 2) arbitrary axisymmetric magnetic geometry, 3) general fluid moment closure relations (both kinetically-deduced and collisional Braginskii), and 4) transport evolution of fluid flows in addition to the usual $n_e$, $T_e$ etc. transport. This is being done to develop a framework for assessing the importance of various 2D and kinetic effects in the pedestal, and for providing a rigorous set of useful 2D plasma transport equations.

*Research supported by U.S. DoE grant DE-FG02-92ER54139.

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[2] W.M. Stacey and R.J. Groebner, Phys. Plasmas **14**, 012501 (2007); *ibid,* **13**, 012513 (2006).