III. THEORY, ANALYSIS AND CODE DEVELOPMENT

A. NEUTRAL PARTICLE TRANSPORT

Extensions of the TEP methodology

(Dingkang Zhang, J. Mandrekas, W.M. Stacey)

Extensive comparisons of GTNEUT predictions against Monte Carlo calculations and experimental measurements in DIII-D, have demonstrated the accuracy and computational efficiency of the TEP method for a wide range of conditions. However, calculations of detailed model problems designed to test approximations in limiting cases have identified two main areas in which extensions in the original TEP methodology would be useful: 1) taking anisotropy into account in the calculation of first-flight transmission coefficients when the neutral mean free path (mfp) is much larger than the characteristic dimension of the computational region; and 2) taking into account that the escape of scattered or charge-exchanged neutrals is preferentially across the incident surface when the mfp is small compared to the characteristic dimension of the computational region.

The TEP methodology has been recently extended[1] to address the above issues. To improve the accuracy of the TEP method in cases where the neutral distribution function at the interfaces is expected to be anisotropic, the original DP_0 approximation was extended to include linearly (DP_1) and quadratically (DP_2) anisotropic distributions.

Benchmarking calculations with Monte Carlo indicate that the DP_1 calculation is significantly better than the original DP_0 calculation for model problems chosen to accentuate anisotropy, but there is little advantage to further extending the calculation to DP_2. This is shown in Fig. 5, where the neutral densities predicted by the DP_0, DP_1, and DP_2 approximations in GTNEUT are compared with the DEGAS Monte Carlo code for a one-dimensional model problem in a purely ionizing medium (charge exchange fraction $c = 0$) and with a mfp to grid size ratio λ/Δ equal to 0.5.

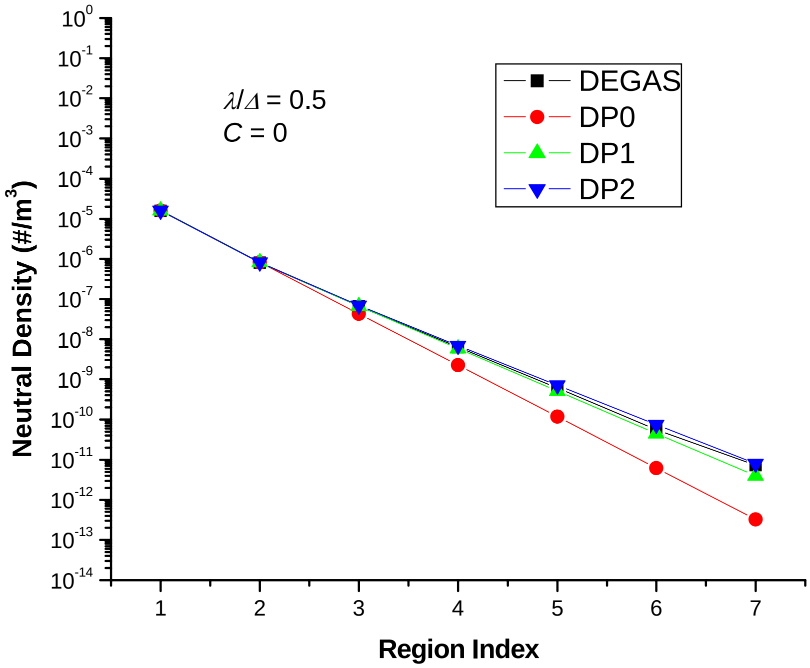

Figure 5: Comparison of neutral density attenuation in a 1-D plane configuration for different approximations.

Work is also underway to address the second of the issues identified above, i.e. the potential inaccuracy of the TEP methodology in regions of small neutral mfp relative to the characteristic dimensions of the region, due to strong non-uniformities in the first collision charge exchange source.. Our first approach has been to introduce a correction to the directional escape probability term based on the *albedo* coefficient[1]. This was suggested by the fact that if the neutral mfp is much smaller than the characteristic dimension of a region, we can treat it as an infinite half space and express the fraction of the collided particles that is scattered back across the incident surface in terms of the albedo coefficient**.** Preliminary simulations and benchmarks with Monte Carlo are encouraging[1].

LLNL Collaboration

(J. Mandrekas, Dingkang Zhang, M. Umansky, T. Rognlien)

The computational speed of the GTNEUT code as well as the deterministic nature of the TEP methodology which leads to noise-free simulations, make GTNEUT an ideal code for coupling with 2-D fluid edge codes. Since the 2D edge fluid code UEDGE is the predominant edge fluid code used in US fusion laboratories, the coupling of the GTNEUT and UEDGE codes has always been an eventual goal of our code development effort.

Following preliminary discussions with the developers of the UEDGE code at LLNL, we have undertaken a series of testing and benchmarking simulations between the GTNEUT code and the fluid neutral model of UEDGE. The goal of these simulations, which are being carried out with the collaboration of Maxim Umansky of LLNL, is to ascertain the strengths of the GTNEUT code vis-à-vis UEDGE's existing fluid neutrals model for a variety of background plasma conditions and, especially, for those conditions where the fluid approximation for the neutrals is expected to be invalid. The results of these simulations will help us decide whether to proceed to the next step, i.e. the implementation of GTNEUT as a routine in the UEDGE code.

1. Dingkang Zhang, J. Mandrekas, and W. M. Stacey, “Extensions of the TEP neutral transport methodology,” to be published in *Contrib. Plasma Phys*., 2004.

B. TOROIDAL ROTATION AND RADIAL ELECTRIC FIELD IN EDGE PEDESTAL (W. M. Stacey)

A model for ion toroidal velocities and the radial electric field in the edge pedestal region of tokamaks has been developed. The model is based on particle and momentum balance and incorporates the neoclassical gyroviscous toroidal viscous force. The toroidal rotation is driven by the input beam torque ($RM_{\varphi j}$), the input torque associated with the induced field ($Rn_j e_j E_\varphi$), and by the internal torque due to the radial ion flow ($e_j B_\theta \Gamma_j$), and depends on the radial transfer rate of toroidal angular momentum ($\nu_{dj}*$) due to viscous, atomic physics and convective effects and on the interspecies momentum exchange rate (ν_{jk}). The local electric field depends on the total local input momentum deposition ($M_\varphi = \Sigma_j M_{\varphi j}$), the local radial pressure gradients (P_j'), the local poloidal velocities ($\upsilon_{\theta j}$) and the local values of the radial momentum transfer rates ($\nu_{dj}*$) due to viscous, atomic physics and convective effects.

This calculation model predicts carbon toroidal rotation velocities in the DIII-D edge pedestal to within about a factor of 2 or better, for a wide range of edge pedestal parameters. This result is consistent with the recent observation[1] that the measured momentum transport frequency through the edge pedestal was within about a factor of 2 of the neoclassical gyroviscous prediction, over this same set of edge pedestal conditions. These results provide a measure of confidence in the calculation model for toroidal rotation in the edge pedestal that was presented in this paper.

A paper has been prepared and submitted to Physics of Plasmas[1].

1. 1. W. M. Stacey, “Investigation of Transport in the DIII-D Edge Pedestal”, Phys. Plasmas, submitted (2003).