Comparisons of paleoclassical based pedestal model predictions of electron quantities to measured DIII-D H-mode profiles

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Abstract.

Accurately predicting the pedestal structure in high-(H-)confinement mode plasmas is of great importance for the modelling of future tokamak plasmas. The main predictions of a model of pedestal structure based on paleoclassical transport as the main transport mechanism are presented. Numerical evaluations of this model are compared with a database of measured DIII-D H-mode pedestal profiles. Across the database, the electron temperature gradient is overpredicted by a factor of 1.7 ± 1.1 and the electron density by a factor of 2.1 ± 0.7. These results are consistent with paleoclassical transport producing the minimum level of electron transport. Trends in the predictions indicate that some additional transport may be operative, especially in high β_{p} and low confinement plasmas.

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Appendix A. The derivation of (13)

Start with the electron and ion versions of (2), including the paleoclassical heat diffusion operator and neglecting any additional Υ

$$-\frac{M+1}{V'}\frac{\mathrm{d}^2}{\mathrm{d}\rho^2}\left(V'\bar{D}_\eta\frac{3}{2}n_\mathrm{e}T_\mathrm{e}\right)+\frac{1}{V'}\frac{\mathrm{d}}{\mathrm{d}\rho}\left[V'\left(\frac{5}{2}T_\mathrm{e}\Gamma\right)\right]=\langle Q_\mathrm{e}^\mathrm{net}\rangle \tag{A.1}$$

$$-\frac{1}{V'}\frac{\mathrm{d}^2}{\mathrm{d}\rho^2}\left(V'\bar{D}_\eta\frac{3}{2}n_\mathrm{i}T_\mathrm{i}\right)+\frac{1}{V'}\frac{\mathrm{d}}{\mathrm{d}\rho}\left[V'\left(\frac{5}{2}T_\mathrm{i}\Gamma\right)\right]=\langle Q_\mathrm{i}^\mathrm{net}\rangle \quad . \tag{A.2}$$

Next, multiply (A.1) by $V'/(M+1)$, and (A.2) by V', and integrate each from ρ to a to get

$$-\frac{\mathrm{d}}{\mathrm{d}\rho}\left(V'\bar{D}_\eta\frac{3}{2}n_\mathrm{e}T_\mathrm{e}\right)=P_\mathrm{e} \tag{A.3}$$

$$-\frac{\mathrm{d}}{\mathrm{d}\rho}\left(V'\bar{D}_\eta\frac{3}{2}n_\mathrm{i}T_\mathrm{i}\right)=P_\mathrm{i} \quad . \tag{A.4}$$

Use has been made of (9) and the ion version of (9) with $M = 0$. Now add together (A.3) and (A.4) to yield

$$-\frac{\mathrm{d}}{\mathrm{d}\rho}\left[V'\bar{D}_\eta\frac{3}{2}n_\mathrm{e}\left(T_\mathrm{e}+n_\mathrm{i}T_\mathrm{i}/n_\mathrm{e}\right)\right]=P_\mathrm{e}+P_\mathrm{i} \quad . \tag{A.5}$$

Splitting the derivative and making use of the derivative of (6) yields

$$-(3/2)V'\bar{D}_\eta n_\mathrm{e}\frac{\mathrm{d}}{\mathrm{d}\rho}\left(T_\mathrm{e}+n_\mathrm{i}T_\mathrm{i}/n_\mathrm{e}\right)=P_\mathrm{e}+P_\mathrm{i}+(3/2)\dot{N}_\mathrm{e}\left(T_\mathrm{e}+n_\mathrm{i}T_\mathrm{i}/n_\mathrm{e}\right) \; . \tag{A.6}$$

Finally, $\mathrm{d}T_\mathrm{e}/\mathrm{d}\rho$ is factored out of the left hand side and terms are rearranged to obtain (13)

$$-\frac{\mathrm{d}T_\mathrm{e}^\mathrm{pc}}{\mathrm{d}\rho}=\frac{(P_\mathrm{e}+P_\mathrm{i})/2-\frac{3}{4}\dot{N}_\mathrm{e}(T_\mathrm{e}+n_\mathrm{i}T_\mathrm{i}/n_\mathrm{e})}{\frac{3}{2}V'\bar{D}_\eta n_\mathrm{e}}\frac{2}{1+\left(n_\mathrm{i}T_\mathrm{i}/n_\mathrm{e}\right)'/T_\mathrm{e}'} \quad . \tag{A.7}$$