Turbulence and Transport in Fusion Plasmas
Part XI

DIFFER

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Wednesday Recap

Yesterday, we

- constructed and deployed quasilinear models based on drift-kinetics and our fluid model
- learned what transport modeling and, more generally, integrated modeling means
- derived transport equations
- saw how integrated modeling can help us understand experiments better

Next step: write our own transport code

Group Work: Integrated Modeling

0.5 days group work:

1. [optional, if using IDL template] Install `gnudatalanguage`, be set up to run `Tsolve.pro`
2. Using either ITER-like parameters in SI or appropriate normalized units, implement ion temperature balance

$$\frac{3}{2}\frac{\partial r n_\mathrm{i} T_\mathrm{i}}{\partial t} - \frac{\partial}{\partial r}\left(r n_\mathrm{i} \chi \frac{\partial T_\mathrm{i}}{\partial r} \right) = r P_\mathrm{ext}$$

   (assume constant-in-time n_i and χ profiles, Gaussian power deposition)
3. Think up sensible boundary conditions
4. Test what happens when Δt chosen too large
5. Does the behavior match expectations? Qualitative & time scale?
6. How sensitive is the fusion power to $T_\mathrm{i}(r = a)$?

Group Work: Integrated Modeling

7. Get Artaud NF 2010 (good source for research project), implement T_e equation and $Q_{\mathrm{ie,ei}}$ energy exchange
8. Implement a more realistic diffusivity model,
   $\chi = \chi_{\mathrm{gyroBohm}}(\omega_T - \omega_{T,\mathrm{crit}})^2$ ponder ITG vs. TEM modifier
   (take above $\omega_{T,\mathrm{crit}}$ from Guo PoFB 1993, Eq. (22))
9. Add a small mock-up neoclassical flux, can be constant in r
10. Add current, q, $\hat{s}$ profiles according to Wesson, *Tokamaks*

$$\begin{aligned} \text{current density} \quad j(r) &= j_0 \left(1 - \frac{r^2}{a^2}\right)^3 \\ \text{current} \quad I(r) &= 2\pi \int_0^r j(r') r' \mathrm{d}r' \\ \text{safety factor} \quad q(r) &= \frac{2\pi r^2 B_\phi}{\mu_0 I(r) R} \end{aligned}$$

11. Explore the impact of all these improvements

Group Work: Journal Club

0.5 days group work:

Pick a turbulence paper, read, digest, present; suggestions:

- M. Albergante *et al.*, *Microturbulence driven transport of energetic ions in the ITER steady-state scenario*, Nucl. Fusion **50**, 084013 (2010)
- R.E. Waltz *et al.*, *Gyrokinetic simulation tests of quasilinear and tracer transport*, Phys. Plasmas **16**, 072303 (2009)
- P. Mantica *et al.*, *Progress and challenges in understanding core transport in tokamaks in support to ITER operations*, Plasma Phys. Control. Fusion **62**, 014021 (2020)
- F. Merz and F. Jenko, *Nonlinear Saturation of Trapped Electron Modes via Perpendicular Particle Diffusion*, Phys. Rev. Lett. **100**, 035005 (2008)

Research Project Suggestions I

Pick one of these or come up with your own

Turbulence topics

- Write and deploy an eigenvalue solver, test against initial-value or theory, investigate stable modes
- Perform and interpret scans over physical parameters with an upgraded version of our Vlasov code
- Write a drift-kinetic dispersion relation solver including the plasma Z function
- Analytically produce a closed fluid model for slab ITG and compare it to the results from the drift-kinetic Vlasov code

Research Project Suggestions II

Pick one of these or come up with your own

Transport topics

Study core predictions and pedestal scaling impact on scenario performance, comparing to literature; focus on one of

- scalings of magnetic field and machine size
- impact of total current and current profile
- coupling/decoupling of T_i and T_e in strongly electron-heated discharges