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Studies of Local and Nonlocal Models of Parallel Heat Flow *

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Abstract

A general closure for the parallel heat flow [1] is presented in this work. This closure has an integral form and is more correct in capturing longer scale length contributions due to superimposed, secondary electron temperature perturbations. The efficacy of this closure in modelling phenomena associated with electron heat transport persists throughout all regimes of collisionality- from highly collisional to nearly-collisionless. In contrast with the diffusive form of parallel heat flow, which is proportional to the local gradient in electron temperature, the general closure involves the integrated effect of temperature perturbations over longer scale lengths. Evidently, both the diffusive and general closure give similar results for effects due to local, primary electron-temperature perturbations, in plasmas of high collisionality. In moderately collisional regimes, $\kappa_{\parallel}$ must be properly chosen for results to agree. However, effects due to secondary temperature perturbations are better captured only by the general closure.

To ascertain the validity and relevance of the general closure, as a new tool for extracting more accurate kinetic physics, model calculations of plasma temperature evolution in slab geometry[2] were developed and run using NIMROD. The linear slab geometry has a periodic length in the phi-direction of 2π, is periodic in the Z-direction with 5m length and has a width of 1m in the R-direction. The magnetic field at work here is built from three components- a sheared equilibrium magnetic field and a primary (n=0) perturbative field that together produce a magnetic island; and a secondary (n=1) perturbative field that leads to chaos or stochasticity near the island separatrix. The primary and secondary perturbative fields possess different scale lengths, characterized by $k_{\parallel n=0}/k_{\parallel n=1} \sim 10$.

NIMROD simulation runs comprised scans of various plasma parameters. Specifically the amplitude of n=1 perturbation and T_{e0} were independently varied, and the corresponding effect on parallel heat flow was measured. Temperature is evolved to steady state using either the diffusive or general closure, starting from a perpendicular heat flux boundary condition. Results show that the general closure results in more enhanced flattening of temperature along field lines when multiple scale lengths are present in the vicinity of a single-helicity magnetic island, characterized by finite stochasticity.

References

[1] E. D. Held, J. D. Callen, C. C. Hegna and C. R. Sovinec, Phys. Plasmas **8**, 1171 (2001).
[2] T.A. Gianakon et al., (Work-in-Progress)

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