Dissipative Closures for Statistical Moments, Fluid Moments, and Subgrid Scales in Plasma Turbulence

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Abstract

Closures are necessary in the study physical systems with large numbers of degrees of freedom when it is only possible to compute a small number of modes. The modes that are to be computed, the resolved modes, are coupled to unresolved modes that must be estimated. This thesis focuses on dissipative closures models for two problems that arises in the study of plasma turbulence: the fluid moment closure problem and the subgrid scale closure problem.

The fluid moment closures of Hammett and Perkins (1990) were originally applied to a one-dimensional kinetic equation, the Vlasov equation. These closures are generalized in this thesis and applied to the stochastic oscillator problem, a standard paradigm problem for statistical closures. The linear theory of the Hammett–Perkins closures is shown to converge with increasing numbers of moments.

A novel parameterized hyperviscosity is proposed for two-dimensional drift-wave turbulence. The magnitude and exponent of the hyperviscosity are expressed as functions of the large scale advection velocity. Traditionally hyperviscosities are applied to simulations with a fixed exponent that must be arbitrarily chosen. Expressing the exponent as a function of the simulation parameters eliminates this ambiguity. These functions are parameterized by comparing the hyperviscous dissipation to the subgrid dissipation calculated from direct numerical simulations. Tests of the parameterization demonstrate that it performs better than using no additional damping term or than using a standard hyperviscosity.

Heuristic arguments are presented to extend this hyperviscosity model to three-dimensional (3D) drift-wave turbulence where eddies are highly elongated along the field line. Preliminary results indicate that this generalized 3D hyperviscosity is capable of reducing the resolution requirements for 3D gyrofluid turbulence simulations.

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