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Multidimensional kinetic simulations using dissipative closures and other *reduced* Vlasov methods for differing particle magnetizations[1]

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Kinetic plasma simulations in which the phase-space distribution functions are advanced directly via the coupled Vlasov and Poisson (or Maxwell) equations—better known simply as *Vlasov* simulations—provide a valuable low-noise complement to the more commonly employed Particle-in-Cell (PIC) simulations. However, in more than one spatial dimension Vlasov simulations become numerically demanding due to the high dimensionality of $\mathbf{x}$–$\mathbf{v}$ phase-space. Methods that can reduce this computational demand are therefore highly desirable. Several such methods will be presented, which treat the phase-space dynamics along a dominant dimension (e.g., parallel to a beam or current) with the full Vlasov propagator, while employing a *reduced* description, such as moment equations, for the evolution perpendicular to the dominant dimension. A key difference between the moment-based (and other reduced) methods considered here and standard fluid methods is that the moments are now functions of a phase-space coordinate (e.g. moments of v_y in z–v_z–y phase space, where z is the dominant dimension), rather than functions of spatial coordinates alone. Of course, moment-based methods require closure. For effectively unmagnetized species, new dissipative closure methods inspired by those of Hammett and Perkins [*PRL*, **64**, 3019 (1990)] have been developed, which exactly reproduce the linear electrostatic response for a broad class of distributions with power-law tails, as are commonly measured in space plasmas. The nonlinear response, which requires more care, will also be discussed. For weakly magnetized species (i.e., $\Omega_s < \omega_s$) an alternative algorithm has been developed in which the distributions are assumed to gyrate about the magnetic field with a fixed nominal perpendicular "thermal" velocity, thereby reducing the required phase-space dimension by one. These reduced algorithms have been incorporated into 2-D codes used to study the evolution of nonlinear structures such as double layers and electron holes in Earth's auroral zone.

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