Integrating Kinetic Effects in Fluid Models for Magnetic Reconnection

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The integration of kinetic effects in global fluid models is a grand challenge in space plasma physics, and has implication for our ability to model space weather in collisionless plasma environments such as the Earth's magnetosphere. We propose an extensible multi-fluid moment model, with focus on the physics of magnetic reconnection. This model evolves the full Maxwell equations, and simultaneously moments of the Vlasov-Maxwell equation for each species in the plasma. Effects like the Hall effect, the electron inertia, and the pressure gradient are self-consistently embedded in the resulting multi-fluid moment equations, without the need to explicitly solving a generalized Ohm's law. Two limits of the multi-fluid moment model are discussed, namely, the five-moment limit that evolves a scalar pressures for each species, and the ten-moment limit that evolves the full anisotropic, non-gyrotropic pressure tensor. Particularly, the five-moment model reduces to the widely used Hall Magnetohydrodynamics model under the assumptions of vanishing electron inertia, infinite speed of light, and quasi-neutrality. In this presentation, we compare ten-moment and fully kinetic Particle-In-Cell simulations of a large scale Harris sheet reconnection problem, where the ten-moment equations are closed with a local linear collisionless approximation for the heat flux. The ten-moment simulation gives reasonable agreement with the Particle-In-Cell results, regarding the electron flows, the polarities and magnitudes of elements of the electron pressure tensor, and the decomposition of the generalized Ohm’s law. Possible ways to improve the simple closure towards a non-local, fully three-dimensional description are also discussed.