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A finite volume formulation of the multi-moment advection scheme for Vlasov simulations

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The Vlasov simulation is known as one of plasma kinetic simulation methods, in which the Vlasov equation is discretized on grid points in phase space. Compared to the Particle-In-Cell (PIC) method, the Vlasov simulation is free from the statistical noise and is easy for parallel computation. On the other hand, the Vlasov simulation has the difficulty in advancing the distribution function in velocity space. Especially, the Vlasov simulation of magnetized plasma is quite difficult, owing to the gyro motion around the magnetic field line (solid body rotation in velocity space).

To overcome the difficulty, we have developed a multi-moment advection scheme (Minoshima et al. 2011; 2013). The scheme treats not only point values of a profile but also its zeroth to second order piecewise moments as dependent variables. The scheme remarkably reduces numerical diffusion and is suitable for advancing the distribution function in velocity space. We have successfully applied the scheme to electromagnetic Vlasov simulations.

Here, we newly propose a simplified form of the multi-moment advection scheme. The new scheme treats zeroth to second order piecewise moments as dependent variables at cell center, while point values of a profile are not. Then the scheme adopts a collocated grid system. The basic equation is discretized in a finite volume formulation. A numerical flux at cell face is evaluated by a one-dimensional high-order interpolation, even in multi-dimensional problems. These modifications greatly simplify the scheme compared to the previous one. Benchmark tests of a multi-dimensional advection and rotation problem show that the new scheme keeps profile well for very long time calculation (˜1,000 rotations). The application of the scheme to electromagnetic Vlasov simulations will be presented.

Keywords: Vlasov simulations