GeFi-E&B: A New Particle Simulation Scheme using Electromagnetic Fields

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— A gyrokinetic electron and fully kinetic ion (i.e., GeFi) particle simulation scheme, valid for fluctuations with wave frequency up to $\omega << \Omega_e$ has been developed [Lin et al., 2005, 2011]. Here, $\Omega_e$ is the electron cyclotron frequency. Such scheme is applicable for simulating plasma dynamics in which the wave modes ranging from Alfvén waves to lower-hybrid/whistler waves must be handled on an equal footing; e.g., the physics of collisionless magnetic reconnection with a finite guide field and lower hybrid/whistler mode waves in space and laboratory fusion plasmas, while employing the realistic ion-to-electron mass ratio. In the gyrokinetic treatment, field equations are usually described by the scalar ($\delta \varphi$) and vector ($\delta A$) potential variables. Poisson’s equations are thus needed to solve for the electromagnetic fields and may present computational challenges for realistic nonuniform and multidimensional magnetic field geometries. Here, we present a new GeFi particle simulation scheme that employs the electric field $E$ and magnetic field $B$ directly as field variables and advances particles accordingly. Contrary to previous hybrid simulation models based on the field variables, the present scheme (GeFi-E&B) also treats the displacement current self-consistently and, thus, includes space-charge waves. A corresponding nonlinear gyrokinetic equation in terms of electromagnetic fields is also derived. For the case of linear waves in a uniform plasma, simulation results are successfully benchmarked against the analytically derived linear dispersion relations.