# Development of a MHD code satisfying solenoidal magnetic field condition and its application to Mercury's magnetosphere

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From the past observations by Mariner 10, it was suggested that the Mercury's magnetosphere might be analogous to the geomagnetosphere. The temporal and spatial scales of the Mercury's magnetosphere is, however, much smaller than those in the geomagnetosphere because of its week intrinsic magnetic field and dynamic pressure of the solar wind. It is pointed out that the kinetic effect, neglected in magnetohydrodynamics (MHD), may not be negligible in some regions of the Mercury's magnetosphere because of its small spatial scale compared with gyro-radius of ions.

Statistical trajectory tracings of test particles (test particle simulation) is one of the important schemes to investigate the kinetic effect of particles. Recent studies by Delcourt et al. [2003; 2005] used analytical models of electric and magnetic fields that are obtained by rescaling the geomagnetosphere. And it is noted that resultant properties largely depend on the field models. Thus usage of more realistic global field configuration of the Mercury's magnetosphere might change some of results of the test particle simulations.

In this study, we developed a new MHD simulation code that automatically satisfies solenoidal condition for the magnetic field (B) i.e., divB=0 to establish a self-consistent electric and magnetic field configuration of Mercury's magnetosphere. It is noted that finite divB causes artificial acceleration/deceleration and satisfaction of the solenoidal B field condition is important especially in the test particle simulations. To fulfill the condition, we used vector potential (A) instead of magnetic field itself in the MHD equation. The usage of the vector potential automatically guarantees div(rotA)=divB=0. For accurate simulation of high Reynolds number magnetofluid (low numerical viscosity), we adopted R-CIP algorithm [Yabe et al., 1991; Xiao et al., 1996] to solve the advection term in the simulation code. The non-advection terms are solved by 3rd order Adams-Moulton predictor-corrector method and 4th order Runge-Kutta method. The code assessment shows good ability of the developed MHD code in Alfven wave propagation, shock tube problem, and Kelvin-Helmholtz instability. A remarkable feature of the new code with A is the precise description of Alfven wave propagation compared to the code with B even for high wave number regime near the Nyquist wavelength.

After the code assessment, we apply this code to the global simulation of Mercury's magnetosphere. We devised boundary conditions suitable for the vector potential code and solved perturbed magnetic field separately from the background magnetic field consisting of the mirror dipoles. The initial result with the constant solar wind shows formation of the bow shock, magnetopause, and cusp like structure at expected positions from the past study, and ejection of