A Novel High-Moment Multifluid Model for Mercury: From the Planetary Conducting Core to the Dynamic Magnetosphere

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We have developed a novel three-dimensional ten-moment multifluid model and applied it to investigate the tightly coupled interior-magnetosphere system of Mercury. This new multifluid model self-consistently solves the continuity, momentum and pressure tensor equations of each species, together with the full Maxwell equations. As a result, non-ideal effects including the Hall effect, inertia, and tensorial pressures are self-consistently embedded without the need for explicitly solving a generalized Ohm's law.

Our simulation results from this new model are in good agreement with observations from MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft. The model is able to reproduce the magnetic field vectors, field-aligned currents and cross-tail current sheet asymmetry observed by MESSENGER. We also investigate collisionless magnetic reconnection in Mercury's magnetotail and at dayside magnetopause. In addition, we study the magnetospheric response of Mercury to a hypothetical extreme event with an enhanced solar wind dynamic pressure, which demonstrates the significance of electromagnetic induction effects resulting from the coupled interior. Moreover, two plasmoids (or flux ropes) are formed in Mercury's cross-tail current sheet during this hypothetical extreme event, indicating the extremely dynamic nature of Mercury's magnetotail. Thus, this novel high-moment, multifluid, interior-magnetosphere-coupled model is crucial for understanding Mercury's dynamic magnetosphere and has the potential to enhance the science returns of both the MESSENGER and BepiColombo missions.

Keywords: Mercury's dynamic magnetosphere, ten-moment multifluid model, induction effect, tightly coupled interior-magnetosphere system, collisionless magnetic reconnection, extreme events