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Development of Multi-hierarchy Simulation Model for Studies of Magnetic Reconnection

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Abstract. The multi-hierarchy simulation model for magnetic reconnection is developed, where both micro and macro hierarchies are expressed consistently and simultaneously. Two hierarchies are connected smoothly by shake-hand scheme. As a numerical test, propagation of one-dimensional Alfvén wave is examined using the multi-hierarchy simulation model. It is found that waves smoothly pass through from macro to micro hierarchies and *vice versa*.

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Key words: Multi-hierarchy, magnetic reconnection, MHD, particle-in-cell.

1 Introduction

Magnetic reconnection is a fundamental process to lead to the fast energy release from magnetic field to plasmas. For instance, solar flares [1,2], Earth magnetic substorms [3], and tokamak disruptions [4] are widely believed to be triggered by magnetic reconnection. Even though magnetic reconnection causes macroscopic phenomenon that global field topology changes, such high-temperature and low-density plasmas are collisionless, and frozen-in condition is satisfied macroscopically. Hence, occurrence of magnetic reconnection requires microscopic processes which break the frozen-in constraint. Namely, magnetic reconnection is a phenomenon bridging across different hierarchies, and thus the full understanding of magnetic reconnection needs a multi-hierarchy model which can deal with both microscopic and macroscopic physics consistently and simultaneously [5].

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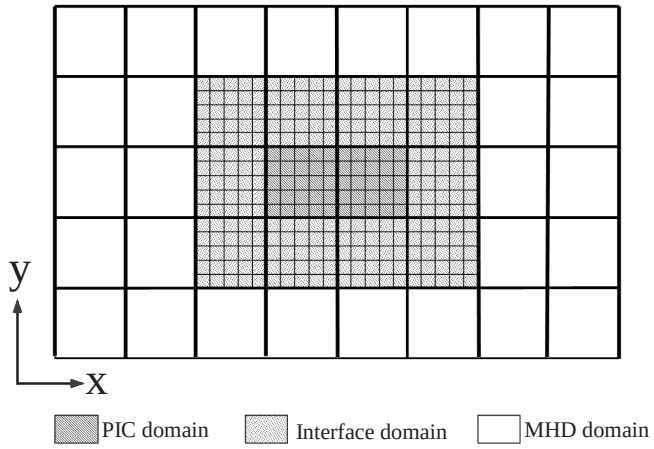

Figure 1: Schematic diagram of multi-hierarchy model. Simulation domain is divided into three domains; PIC, MHD, and Interface domains.

In this paper, we propose a multi-hierarchy simulation model which we are developing. In Section 2, we explain our multi-hierarchy model. Numerical methods to interlock between different hierarchies are shown. In Section 3, we examine our model. It is observed that one-dimensional Alfvén wave smoothly propagates in a multi-hierarchy simulation box. In Section 4, we discuss problems on the multi-hierarchy simulation demonstrated in Section 3. Section 5 gives a summary of our work.

2 Multi-hierarchy simulation scheme

In this section, we describe algorithm for multi-hierarchy simulation of magnetic reconnection, i.e., two hierarchies which make up our model, how to interlock two hierarchies smoothly, unit transformation, and data exchange.

2.1 Two hierarchies

Our multi-hierarchy model is based on the domain division method, and thus is composed of two hierarchies: micro hierarchy and macro hierarchy. The neighborhood of reconnection points is micro hierarchy, where microscopic kinetic effects play crucial roles, and frozen-in condition is violated. Dynamics in this system are solved by explicit electromagnetic particle-in-cell (PIC) simulation [6–9]. Let us give the name 'PIC domain' to this domain. On the other hand, the surrounding of PIC domain is described by magnetohydrodynamic (MHD) simulation [10]. In 'MHD domain', ideal MHD equations are applicable, since non-ideal effects leading to the generation of electric resistivity and viscosity are assumed to be generated by microscopic physics in the vicinity of reconnection points [11–13].