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Investigations of treatment of the magnetic field in a dynamo simulation using the FEM

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1. Introduction

We propose a time evolution scheme using a vector potential of magnetic field for MHD dynamo simulation in a rotating spherical shell with the parallel finite element method (FEM). After 1995, several MHD simulations in a rotating spherical shell have represented some of the basic characteristics of the Earth's magnetic field. However, the dimensionless numbers in these studies were still far from the estimated values for the Earth's outer core. To approach these estimated values in geodynamo simulations, spatial resolutions have to be increased and parallel computations are required. Most of numerical simulations for MHD dynamo in a rotating spherical shell have been performed using the spherical harmonics expansions. The spherical harmonics expansion is not suitable for the parallel computation because a significant number of global operation is required in this scheme.

2. Methods

Consider a rotating spherical shell modeled on the Earth's outer core. The shell is filled by an electrically conductive fluid, and the shell is surrounded by electrically insulator. The most difficult problem to perform the dynamo simulation using FEM is treatments of the electromagnetic field between the conductive fluid and the electrically insulator. Two difficulties exist in this problem; one is that a potential magnetic field in the insulator has to be solved and another is that the magnetic field is solved by the induction equation with satisfying the boundary condition on the boundary. We solve the magnetic field using the vector potential of magnetic field to solve these difficulties. A finite element mesh is not only set for the outer core but inner core and outside of the core. In the present study, radius of the simulation box is set to be 15 times of the width of the fluid shell. The induction equation for the conductive fluid and Laplace equation for the each component of the vector potential in the electrically insulator are solved simultaneously. To solve the entire region simultaneously, the Crank-Nicolson scheme is applied for the time integration. A significant advantage of the scheme is that we treat much simpler scheme than that using the magnetic field because any special treatment is not required to satisfy the boundary conditions between conductive fluid and electrically insulator. The vector potential is set to be 0 on the outer boundary of the simulation box because finite size of simulation box is required in the present simulation.

3. Result of a test simulation

To verify the simulation code, we performed a kinematic dynamo problem and these results are compared with the same simulation by the spherical harmonics expansion. The results have only 3% of difference from that by the spectral method. MHD dynamo simulation will be performed using this scheme and a simulation code for the momentum equation.