Current status of a dynamical model of the heliosphere with the adaptive mesh refinement

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A change in the heliospheric environment plays an important role in the modulation of the galactic cosmic rays; the magnetic field structure and the speed of the solar wind affect the cosmic ray transport in the heliosphere. Since the heliospheric environment is affected by the solar wind activities, we have been developing a framework for simulating the heliosphere by using MHD simulations. The galactic cosmic rays are transported efficiently in the heliospheric current sheet (HCS), and it should be reproduced with a fine resolution in the model. We therefore utilized the adaptive mesh refinement (AMR) technique for improving the local resolution. In this talk, we present outline of our project and show the current status of the model development.

The simulation code is based on SFUMATO code (Matsumoto 2007), which employs the block-structured AMR. The HLLD- scheme (Miyoshi 2007) was adopted for the MHD solver, and it was modified to have a third order of accuracy in space and second order in time.

The time-dependent solar wind model is given by the inner boundary condition of the simulations. This model was ported from the space weather forecast system, SUSANOO (Shiota et al. 2014). It is based on the synoptic maps of the photospheric magnetic field provided by the Global Oscillation Network Group (GONG) project, the potential fields source surface (PFSS) model, and some empirical models for reconstructing the MHD parameters in the inner boundary condition.

For refinement of the grid, two types of the criteria are adopted. The first criterion is the grid-refinement according to the distance between the AMR-block and the Sun. This criterion provides linear increase in a resolution according to the distance from the Sun. The second criterion is the grid-refinement according to the HCS. When the HCS is detected, the AMR-block is refined there. The HCS is detected as a plane in which the toroidal component of the magnetic field vanishes. Due to this criterion, the HCS is resolved by a fine resolution, and numerical diffusion is considerably reduced there. Moreover, the co-rotating interaction regions (CIRs) are resolved sharply because the slow winds exist near the HCS, and the CIRs are also covered by the fine grids. The realistic reproduction of CIRs would also contribute for space weather forecast of the terrestrial radiation belt, which is sensitive to the sharp density enhancement and/or the rapid directional switch of interplanetary magnetic field within the CIRs.

Keywords: Heliosphere, Heliospheric current sheet, Co-rotating interaction regions, MHD simulation, adaptive mesh refinement