次世代スーパーコンピュータで目指す磁気圏グローバルMHDシミュレーション

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Global MHD simulation of the magnetosphere for the next generation HPC: Future perspectives

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Since 1980's the magnetohydrodynamic (MHD) simulation has been a powerful tool for modeling an interaction of the supersonic solar wind plasma with the terrestrial magnetosphere. Increasing computational capability enables us to predict the geospace environment in response to transient solar activities such as the coronal mass ejection (CME), that is, Space Weather forecast. Nowadays, a number of global MHD models have been developed. Those may include BATSRUS, Open GGCM, LFM, Nagoya and Kyushu university's models. However, due to restricted CPU time and a memory capacity, even the modern global MHD models of the magnetosphere solve limited area in the magnetosphere and physical processes. Despite the great progresses on the global MHD simulations, some issues are remained to be solved for future high performance computing, which we address in this presentation.

Exploring the inner magnetosphere ($L<4$), where Alfven speed exceeds 3000 km/s, is one of the challenging issues since the CFL condition based on Alfven speed there limits the time integration. To overcome this difficulty, the nested grid model has been developed to understand a coupling of the magnetosphere with the low latitude ionosphere [Fukazawa, 2007]. The nested grid model consists of two (or more) grid systems. Basic equations are numerically solved with different time steps in each grid system so that the total computational time does not severely increase. At a time interval, the grid systems transfer data to each other across the boundary. Although there remain some numerical difficulties, this is a promising approach for solving the whole magnetosphere in the next generation super computer.

Recent numerical simulations and in-situ observations have shown that turbulence is of particular importance in discussing plasma transport and acceleration in the magnetosphere. For example, the turbulent transport of the solar wind plasma via Kelvin-Helmholtz instability has been proposed by the local numerical simulations [Matsumoto and Hoshino, 2006]. In-situ observations of the high energy electrons in the plasma sheet can be also related to the turbulent magnetic fields [Imada et al., 2005]. Despite its importance, little has been understood in a global MHD simulation. This is mainly due to the numerical resolution in space which severely increases both CPU time and memory consumption. To tackle with this problem, robust and high resolution schemes have been required. Recent global MHD models based on new MHD schemes, for example, HLLD Rieman solver [Miyoshi and Kusano, 2005] and CIP algorithm [Matsumoto and Seki, 2008] will be shown as an application to the next generation super computer.