Full Particle-In-Cell Simulation Study on the Solar Wind Interaction with Small-Scale Magnetic Dipole Field

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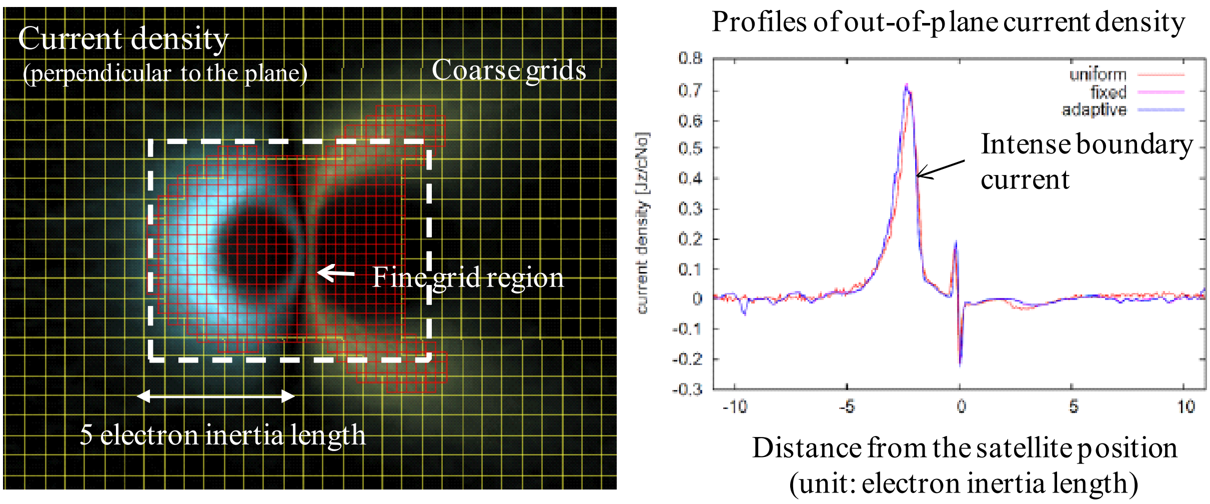
Abstract

We have been investigating the solar wind interaction with a small-scale dipole magnetic field structure comparable to or less than the ion inertial length by performing full particle-in-cell electromagnetic simulation. Such a micro-scale magnetosphere would be used for the next-generation interplanetary flight system called Magneto Plasma Sail (MPS) which has been proposed as one of the innovative interplanetary flight systems by JAXA. In the current paper, we focus on the analysis of current layer caused by the interaction of the solar wind at the boundary of the small dipole field. The current layer is very important for the MPS thrust which can be evaluated with the Lorentz force obtained with the magnetic field component induced by the current layer and the current by a superconducting coil at the satellite. In a situation where the ion inertia length is larger than the dipole field region, it turns out that electron interaction with the local magnetic field becomes important. The ions, which are basically unmagnetized in such as a situation, can be indirectly influenced by the presence of the dipole field due to the electrostatic force cause by the difference from the electron dynamics. We will examine the formation of a small-scale magnetosphere in such a situation as well as the features of the current layer in terms of location, width and intensity.

In addition, IMF effect such as the formation of shock structure and magnetic field reconnection can affect the formation of the current layer. In the preliminary two dimensional PIC simulations, magnetic reconnection takes place at the night side of the magnetosphere even in the northward IMF case. A current density peak is formed inside the magnetosphere due to the electron backflow from the reconnection region, in addition to the induced current density at the front boundary layer where the solar wind momentum is primarily diverted. Consequently, when we consider the IMF effect, we could observe expansion of the dipole field structure and the increase of the MPS thrust at the satellite.

In parallel, we have been developing a new simulation code by incorporating adaptive mesh refinement for multi-scale PIC simulation. A prototype of the code is completed and currently we have been working on the code parallelization with adaptive domain-decomposition scheme using MPI. In the presentation, we will show some of the results obtained with the newly developed multi-scale simulation code and examine the detailed process of the solar wind interaction with a small scale dipole field. We particularly focus on the boundary region where the magnetic field variation and the current density is large.



Contour map of out-of-plane current density (left panel) and its profile in the equatorial direction (right panel). Fine grids are adaptively generated at the boundary current layer where the variation of magnetic fields is large.

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