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Development of Space Weather simulation and prospect for the practical use

Takashi Tanaka[1]

[1] Kyushu University

The Sun-Earth system is a complex natural system interconnecting many different regions, i.e. sun-corona-solar wind-magnetosphere-ionosphere. The disturbance phenomena occurring in this complex system is called the space weather. Kyushu University and its collaborators have been building a space weather modeling system. In this system, the first-principles-based physical models are built for all of the involved domains. All regions have a common mathematical model in the form of magnetohydrodynamic (MHD) equation, common dependent variables, and a common numerical scheme. Today, general frameworks for the numerical simulation are becoming more and more important in the investigation of complex phenomena like the space weather. The numerical method to solve MHD equations employs the finite volume total variation diminishing (TVD) scheme. For this conservative scheme, upwind formula is used to evaluate the flux on the control volume surface to enable stable numerical time integrations.

The Heliospheric structure ranging from the solar surface to the earth's orbit is reproduced as a time varying self-consistent three-dimensional (3D) MHD problem. Here, the observed magnetic field on the solar surface is adopted as a boundary condition, since the solar magnetic field acts an essential role for the generation of large-scale structure and dynamics of the solar corona. The simulation model incorporates gravity, coriori and centrifugal forces into the momentum equation, and coronal heating and field-aligned thermal conduction into the energy equation. The coronal heating is parameterized so as to express the decay process of Alfven waves launched through the release of magnetic twist caused by the granule convection. Thus, relation between the nonlinear decay process of Alfven waves and large scale coronal structure is a typical example of hierarchy and holism.

The transfer process of mass, momentum, and energy from the solar wind to the M-I system and resulting disturbance phenomena are also simulated by the MHD equation. Associated with the dayside reconnection, two cusp nulls appears near the subsolar region. There appears a separator line connecting these two cusp nulls. If the spatial volume is separated into three parts, the volumes that contain closed field lines, open field lines, and IMFs, the interfacing surfaces between these three volumes are defined as two separatrices on which the diffusion region is spreading. The separator line coincides with the intersection of two separatrices. Outside the cusp, the X-type neutral lines are formed to be nearly orthogonal to the IMF direction. After the southward turning of the IMF, the fluxrope is generated with the core By which is the remnant of nightside separator line causing the substorm.