Three-dimensional MHD simulation of the solar wind from the solar surface to 400 solar radii using REPPU (REProduce Plasma Universe) code

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ABSTRACT

Three-dimensional MHD simulation code, REPPU (REProduce Plasma Universe) code, is developed for modeling of space plasma phenomena, and is utilized for the solar surface and the global solar wind structure.

The distinguishing feature of this code is the 3-D grid system, which has no polar singularity. This grid system makes it possible to set fine grids on the inner boundary of the inner simulation region which corresponds to the solar surface REPPU code achieved both the implementations for the fine grid structure on the inner boundary and for the wide range grids in global solar wind configuration.

We extend the outer boundary to 400 solar radius, though the previous model covered 200 solar radii. We split the simulation region at several 30 solar radius where the solar wind speed is super-sonic. This improvement made it possible to perform stable simulation in the outer region where rotational component of the solar wind velocity is high.

REPPU (REProduce Plasma Universe) code (by Tanaka)

REPPU (REProduce Plasma Universe) code

Control volume for the FVM (Finite Volume Method) (Tanaka, 1994)

Simulation Model

The inner boundary is set at 1 Rs.
• Phenomena occurred on the solar surface can be simulated seamlessly toward the earth orbit.
• The outer boundary is extended to 400 solar radii, though the previous model covered 200 solar radii.
• We split the simulation region about several solar radii (300 solar radii) where the solar wind is super-sonic.
• The inner region is developed in a rotational frame and the observed magnetic field data are input on the solar surface as the inner boundary.
• The outer region is simulated in a fixed frame and simulated data in the inner region are set on the inner boundary of this code.

Equations of Motion

\[ \begin{align*}
\dot{\mathbf{v}} &= \nabla \times \mathbf{B} \\
\dot{\mathbf{B}} &= \nabla \times \mathbf{v} \\
\dot{\rho} &= -\nabla \cdot \mathbf{v} \\
\dot{E} &= \nabla \cdot (\mathbf{v} \otimes \mathbf{v}) \\
\dot{M} &= -\nabla \cdot (\mathbf{v} \otimes \mathbf{B}) \\
\dot{S} &= -\nabla \cdot (\mathbf{v} \otimes S) \\
\end{align*} \]

Solar wind acceleration model

We developed the 3D MHD simulation model, REPPU code, for the solar surface and the global solar wind structure. Simulation can be updated once a day though our simulation region includes both near solar surface and the wide region beyond the earth orbit, 400 Rs.

Simulation results including the period when St. Patrick event occurred were presented. Our code could identify that the source of the stream might be the CH in southern solar surface near the earth orbit.

Solar wind structure

Synoptic chart for CR2161 (2/28-3/26), when St. Patrick’s event (3/17) occurred

Confirmation

• One of features that the period for high-speed solar wind continued for about 6 days, comparatively long term is thought to be one of cases of the long geomagnetically disturbance initiated at St. Patrick’s Day event.
• High-speed stream occurred be ejected from the coronal hole (CH) in southern solar surface and we can see that high-speed region in northern hemisphere starting on March 16 (in Fig. 1).
• We used the这些东西 as data on the white horizontal line indicating above. The high-speed region in the northern hemisphere includes the CH and the regions with high-speed stream in the northern hemisphere, which shows the observations data at 04:30 UTC on March 16. This indicates that the CH was the source of the stream.

Summary and Future work

We are preparing for operation to forecast the solar wind condition.

We will input CME models in order to model propagation of CME and predict the arrival time of shock wave associated with the CME.