

Transforming Community Access to Space Science Models

PAGES 153–154

Researching and forecasting the ever changing space environment (often referred to as space weather) and its influence on humans and their activities are model-intensive disciplines. This is true because the physical processes involved are complex, but, in contrast to terrestrial weather, the supporting observations are typically sparse. Models play a vital role in establishing a physically meaningful context for interpreting limited observations, testing theory, and producing both nowcasts and forecasts. For example, with accurate forecasting of hazardous space weather conditions, spacecraft operators can place sensitive systems in safe modes, and power utilities can protect critical network components from damage caused by large currents induced in transmission lines by geomagnetic storms.

As in other scientific communities, the expertise to develop these models is concentrated in a small section of the space science research community. This presents an obvious bottleneck in the community's access to the models that they desperately need. Without help, model developers can support only their own research and that of their immediate collaborators. The bulk of the space science research community is at risk of model starvation, and the return on the investment in the development of these models might not be maximized. Efficient progress in developing and implementing effective space weather forecasting requires a way to break this bottleneck. Model developers often lack experience in preparing their models to meet the very different stresses that they experience in a real operational forecasting environment. But for them, as a group, to acquire this expertise would clearly be an inefficient use of their time and talents.

More than 10 years ago, the space science community recognized that a solution was needed. The Community Coordinated Modeling Center (CCMC; <http://ccmc.gsfc.nasa.gov>) was conceived as a means to improve the community's access to models and to help model developers prepare models for operation.

This original initiative was approved by the Committee for Space Weather and became an integral element of the inter-agency National Space Weather Program. CCMC was subsequently established with a steering committee that included representatives from key stakeholder organizations, including NASA, the National Science Foundation, the Air Force Weather Agency, the Air Force Research Laboratory, the National Oceanic and Atmospheric Administration, and the Office of Naval Research.

CCMC began operations in 2000. Located at NASA Goddard Space Flight Center, in

Greenbelt, Md., it operates a dedicated computing facility that has since grown to host more than 40 space science models. These cover almost all the physical domains of importance to space weather.

The inventory currently includes 6 solar coronal models, 7 inner heliospheric models, 13 models of the Earth's magnetosphere, 9 models of the ionosphere, and 9 models of the thermosphere. A number of these models can be coupled to create more complete simulations of times and space weather events of interest. The models include both static and time-dependent approximations.

CCMC activities fall into three broad categories: executing model runs upon request from researchers in the community, executing model runs in near real time and publicly disseminating the resulting space weather products, and performing validation of the models in a setting independent of the model developers.

Users can request model runs using a Web interface that guides them in specifying any adjustable model parameters and selecting the input data they wish the model to use. CCMC staff review users' requests and then execute them. Upon completion, the model results are posted to CCMC's publicly accessible results database, and users are sent a URL that enables them to browse their results. The Web page to which the URL directs users presents a range of powerful visualization

solutions developed to enable them to explore the results of the run.

For example, Figure 1 illustrates a visualization of a complex flux transfer event (one way in which the solar wind and Earth's magnetosphere exchange mass, energy, and magnetic flux) during a time-dependent simulation of the Earth's magnetosphere run at CCMC using the Space Weather Modeling Framework, which was developed at the University of Michigan. The visualization was created using the Space Weather Explorer tool developed within CCMC. Since its inception, CCMC has executed more than 5000 runs requested by more than 600 different users from 33 countries.

To support NASA's space weather needs, many models are also run with the Space Weather Laboratory, CCMC's parent organization, on a daily, and in some cases continuous, basis, using the latest "real time" data feeds. Results from these near-real time runs are disseminated to the public through the Integrated Space Weather Analysis system (ISWA; <http://iswa.ccmc.gsfc.nasa.gov>), which is updated continually. The ISWA site, which is not strictly part of CCMC, is much more than a simple repository of model results. It is a comprehensive presentation of the current and past state of the space weather environment, combining both observational data and model results in a mutually supporting context. Visitors to ISWA's site can view the current state of the heliosphere or dial the clock back and see the same presentation for times in the past. This "look back" feature is frequently used by flight engineers within NASA to diagnose possible space weather causes of glitches

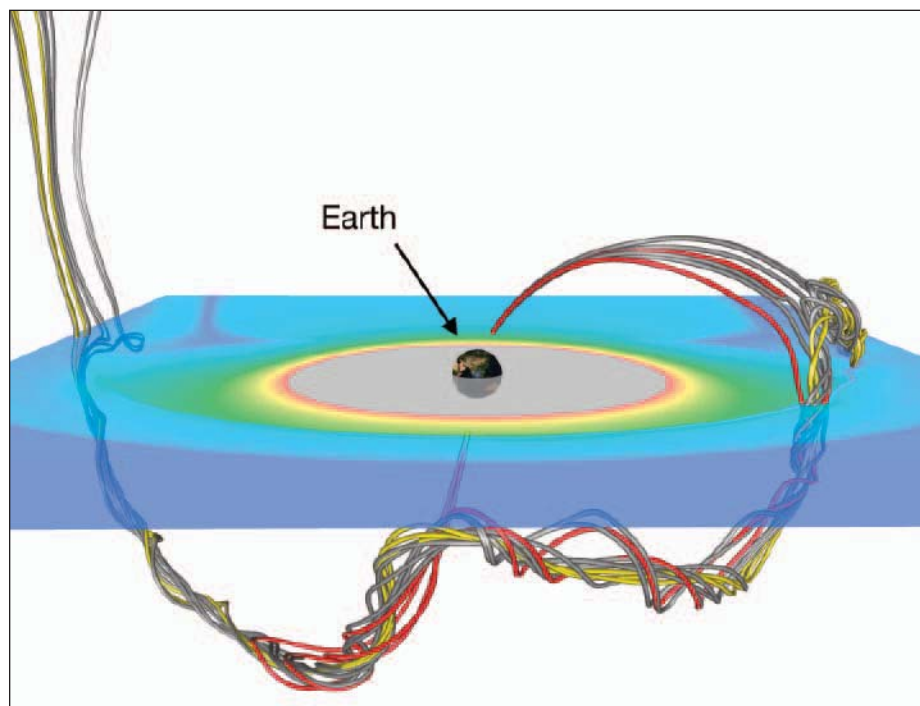


Fig. 1. The complex interweaving of magnetic field lines on the sunward side of Earth during a simulation of a typical flux transfer event at the magnetopause. The Earth is drawn to scale. The color map shows electron density in the equatorial plane (red is higher density; blue is lower density). This image was created using the Space Weather Modeling Framework (SWMF) model and the Space Weather Explorer (SWx) visualization tool.

experienced by spacecraft computers and control systems. Currently, ISWA presents approximately 300 different space weather products. The Space Weather Laboratory has developed both iPhone and Android apps to provide even more portable and timely access to the ISWA system.

Over its lifetime, CCMC has hosted more than 30 summer students, from high schoolers to Ph.D. candidates. It has collaborated with teachers to support classes at U.S. universities and in summer schools, interacting with students as they design and analyze model runs.

The space science community is under pressure to provide useful forecasting products even as its underlying models, and the science that is their foundation, are

rapidly evolving research topics. This contrasts with terrestrial weather forecasting, where the models and underlying science are more mature and model updates, when introduced, are more incremental. Using the same models to support both research and forecasting introduces an obvious tension, which CCMC sees firsthand in its dual roles of supporting user research and operational forecasting. Operating in this exciting but demanding middle ground places a premium on both flexibility and responsiveness. To ensure its continuing success, CCMC must anticipate new developments and plan ahead to accommodate them. To this end, CCMC maintains an active dialogue with its customers and stakeholders, holding

workshops every 2 years and reporting to the community and soliciting feedback and suggestions. The most recent workshop was held in January 2012.

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—PETER MACNEICE, MICHAEL HESSE, MARIA KUZNETSOVA, MARLO MADDOX, LUTZ RASTAETTER, and DAVID BERRIOS, NASA Goddard Space Flight Center (NASA GSFC), Greenbelt, Md.; E-mail: peter.j.macneice@nasa.gov; and ANTTI PULKKINEN, Catholic University of America, Washington, D. C., and NASA GSFC