

CENTER FOR INTEGRATED SPACE WEATHER MODELING CISM

CISM MODELS ENHANCE SPACE WEATHER FORECASTING

Image of the Sun in the extreme ultraviolet range showing the solar corona at a temperature of ~1 million K. Recorded Sept. 11, 1997. Image: SOHO_EIT, <http://sohowww.nascom.nasa.gov/gallery/EIT/eit029.html>



Thanks to the magnetic cocoon surrounding the Earth, many people live out their lives oblivious to the harsh reality of our space environment.

That is, unless you happen to run a power grid in New England, or you're on a polar flight from Chicago to Hong Kong and all the communications are blacked out.

Then you know firsthand that the sun is capable of lashing out with tentacles of radiation that travel through space at enormous speeds and buffet our planet's magnetic shield, wreaking havoc with electrical systems and satellites.

Whether you're combating corrosion in pipeline operations, conducting an offshore survey using high-precision GPS navigation, or just trying to get a clear satellite TV signal, you may be very interested in the latest space weather forecast.

Forging a better understanding of space weather is the mission of the Center for Integrated Space Weather Modeling. CISM researchers are developing new models of the entire system from the sun to the Earth, ones that are more comprehensive and powerful than ever before. And they are working to transition the models into practice in partnership with NOAA's Space Weather Prediction Center (SWPC), Boulder, Colo.

Now in the testing stage, the technology is poised to dramatically improve the quality of space weather forecasting in the near future.

The Forecast Room

It's staffed 24/7, but most days, life is pretty calm in the forecast room at SWPC, says Joe Kunches, chief of the SWPC forecast and analysis branch. Around the room are monitors with real-time data feeds from NOAA and NASA satellites. Operators are eyeing plots of the solar wind speed near Earth, the

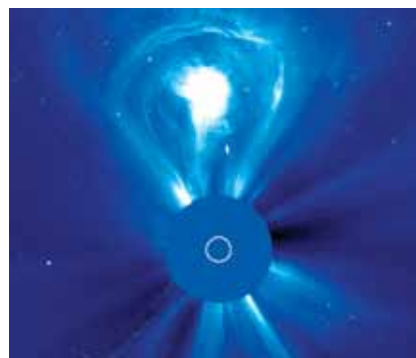
magnetic field in the solar wind, the X-ray flux coming from the sun, and the energetic particle flux.

Conditions can be stable for a long time and then change fast. "When the sun has a flare, the X-ray flux, for example, can increase a millionfold in minutes," says CISM director Jeffrey Hughes.

It's a wild ride. Operators are watching graphs, they're hearing audio alarms. "You've got a whole lot of stuff coming at you very quickly," says Kunches. "You're on the phone, you're sending e-mails, and predicting when the next threshold may be reached or when it will taper off—and all the while the phone is ringing with customers asking, 'What is going to happen to my operation in six, twelve, twenty-four hours?'"

Next-Generation Models

In the past, models were developed to study pieces of the system, rather than to go from the sun to a forecast in a single step. While CISM has improved the models that describe regions of space, they have focused on coupling them together in a "Sun-to-the-Earth" chain.



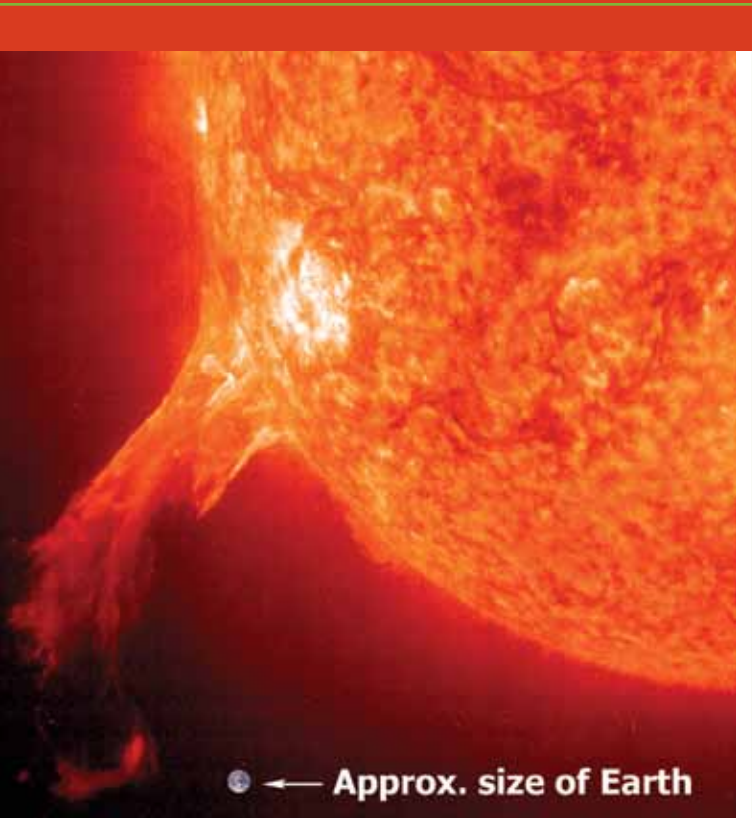
This "lightbulb" coronal mass ejection (CME) shows the three classical parts of a CME: leading edge, void, and core. Taken Feb. 27, 2000 by the LASCO C3 coronagraph. In coronagraph images, direct sunlight is blocked, revealing the surrounding faint corona. The approximate size of the Sun is represented by the white circle. *Image: http://sohowww.nascom.nasa.gov/gallery/top10/top10_detail_c3bulb_cropt.html*

Because of those innovations, two main advances in the forecasting ability of SWPC are expected. First, it will be possible to predict, up to a week in advance, the varying structure of the solar wind, important to forecasting power disruptions. This component went into routine operation at SWPC in fall 2011.

Second, technologies are being transferred to model the magnetosphere and ionosphere. These are important for polar flights and communications. Forecasters will be able to model the Earth's environment from the upper atmosphere (~100 km above sea level to distances just beyond the moon. For comparison, 100 km is below the orbit of the space shuttle (200 km), below satellite orbits (above 400 km), and at the lower boundary of the ionosphere (important for radio transmissions). Operational use is expected in the 2013-2014 time frame.

"The CISM-SWPC partnership is going to accelerate the transition of models into operational practice," says Howard Singer, chief of the SWPC science and technology infusion branch. "We've been able to give CISM researchers information about what the needs are, and they, in turn, provide us models that we can run in our test bed, determine what sort of improvements are needed, and feed that back to the developers. There's a nice synergy here, and a good interaction between scientists, developers, and users." □

At top right: The forecast and analysis branch of NOAA's Space Weather Prediction Center, Boulder, Colo., has the responsibility for providing the nation's real-time space weather services 24 hours per day. *Photo: SEC*



← **Approx. size of Earth**

A closeup of an erupting prominence with Earth inset at the approximate scale of the image. Taken July 1, 2002. Image: SOHO Top 10 Images, <http://sohowww.nascom.nasa.gov/>

EDUCATING THE NEXT GENERATION OF “SUN-TO-EARTH” SCIENTISTS

“Typically our field has thought of itself as several related but separate disciplines—solar physicists, interplanetary medium types, the magnetosphere types, the upper atmosphere specialists,” says CISM director Jeffrey Hughes.

“Part of what CISM is trying to do is to make everybody think, ‘You’re a space-physicist sun-Earth-system person,’” says Hughes. “Maybe you concentrate on a certain piece of it, but you’re studying part of a larger system, and you think of it that way.”

Executive director Jack Quinn contrasts this approach to his own experience. “When we were graduate students, I learned primarily about the Earth’s magnetosphere, and I was involved in team science—because space science has always been team science—but it was teams of other magnetospheric physicists,” he reflects. “Now, the students in CISM are growing up interacting all the time with all of those different, previously separate disciplines—to them, it’s the way it should be. It’s normal.”

Moreover, they’re gaining other professional skills—things like action items, due dates, publishing, fund



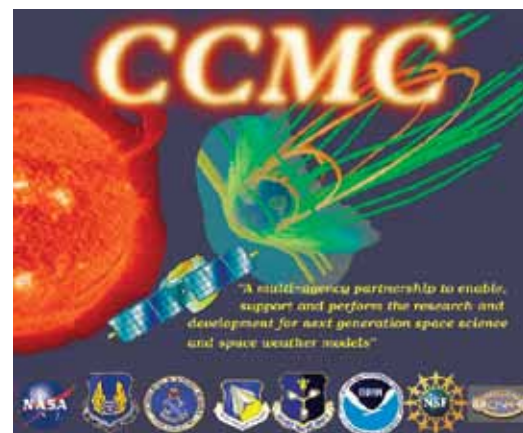
raising, and knowledge transfer. “They’re getting a leg up on what we learned much later on,” says Hughes.

To help prepare incoming graduate students, CISM organizes a space weather summer school. Lectures in the mornings are complemented by hands-on sessions in the afternoon in which students gain experience with CISM models and software.

Part of the transformation taking place is the development of pathways for diverse students to enter the discipline. In order to increase the participation of African American students in this field, CISM has helped establish a graduate program in space science at Alabama A&M University. The effort builds upon an existing undergraduate physics specialty in space science there, “so now a track exists for students to continue their graduate studies as members of the CISM team,” say the CISM directors.

HOW’S THE WEATHER TODAY?

Our planet is bathed in a solar wind—the continuous flow of matter blown away from the sun, traveling through space at speeds of up to 1.5 million miles per hour. The composition of the solar wind resembles the sun itself: mostly protons—hydrogen atoms stripped of their electrons—and other elements. When the particles are trapped along the Earth’s magnetic field lines at high latitude, we see the effects as auroras, the delicate, shifting curtains of light in the night sky. When an aurora is seen at lower latitudes, it’s a sign of solar storms. The largest are caused by solar flares and coronal mass ejections (CMEs). Flares last for minutes or hours and originate in a thin layer close to the sun’s visible surface. They give off energetic particles and high-energy photons, including ultraviolet light, X-rays, and gamma rays. Traveling at the speed of light, the light waves reach the Earth days ahead of particles released in the same event. Flare activity usually follows the 11-year sunspot cycle. CMEs consist of matter thrown out from the corona, the sun’s outer atmosphere, visible as the “halo” during a total eclipse. These events occur when the magnetic field lines get tangled due to different rates of rotation of the sun’s polar and equatorial regions. The tangled lines can snap in a violent explosion, spewing huge volumes of solar atmosphere at speeds of up to several million miles per hour.



CISM MODELS REACH SCIENTISTS AROUND THE WORLD

Want to run your own simulation of space weather? Researchers can, thanks to a multiagency partnership called the Community Coordinated Modeling Center (CCMC). Models developed at CISM and by other scientists are made available over the Web at no cost for use by researchers around the country and the world through the CCMC. <http://ccmc.gsfc.nasa.gov>

NEWS WATCH

A NEW “HEADS UP” ON SOLAR STORMS

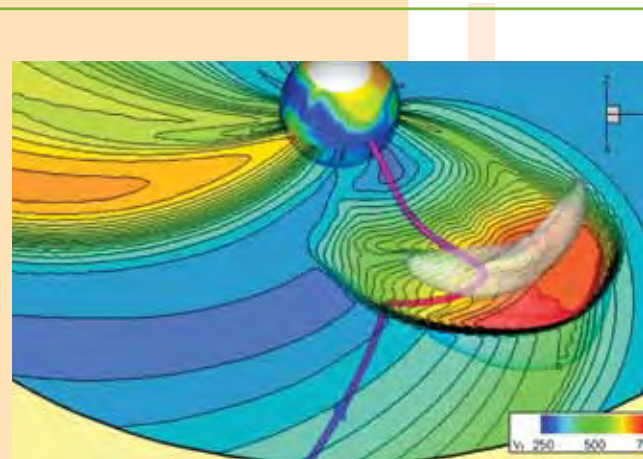
The first physics-based model for predicting space weather transitioned from research to operation in October 2011.

The development responds to the growing need to protect global communications infrastructure from severe space weather disruptions. With the next solar maximum expected by 2013, the deployment comes not a moment too soon.

The model will provide advance warning of high speed streams of solar plasma and coronal mass ejections (CMEs) that may severely disrupt or damage space- and ground-based communications and satellite operations. It's an outgrowth of a partnership between the Center for Integrated Space Weather Modeling (CISM) and the Space Weather Prediction Center of the National Oceanic and Atmospheric Administration (NOAA).

“It's very exciting to pioneer a path from research to operations in space weather,” says CISM director Jeffrey Hughes of Boston University. “The science is having a real impact on the practical problem of predicting when solar storms will affect us here on Earth.”

The model uses maps of the magnetic fields on the surface of the sun, derived from telescope observations, and predicts what the solar wind will be like for the next few days. “It completely revolutionizes how these predictions are made,” says Hughes. Previously, forecasters just estimated the speed of the solar wind and assumed it would have that speed all the way to Earth. “This is actually doing a physics calculation of how the solar wind is going to evolve,” adding that it predicts not only the solar wind at Earth, but at other points in space—“on Venus if you like.” It's a capability likely to grow in importance as space tourism and manned space explorations take flight in the future.



A coronal mass ejection (CME) in a model. The CME is the gray cloud toward the lower right. Image: Dusan Odstrcil, George Mason University

A CONVERSATION WITH THE DIRECTORS

Jeffrey Hughes & Jack Quinn

“If a center is to be successful, it's got to have a clear idea of why it needs to be one, and what it is that makes the center important,” says CISM director Jeffrey Hughes.



CISM director Jeffrey Hughes

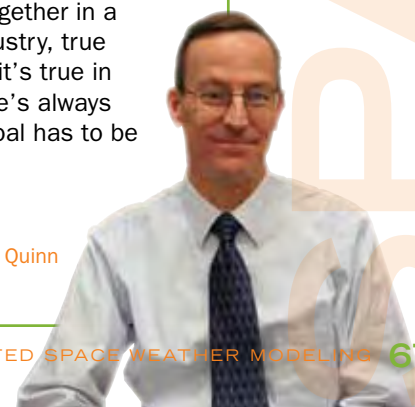
“If the reason is just ‘We're going to enhance research in this field,’ it probably shouldn't be a center. The approach should be employed in carefully selected cases in which the problem warrants this treatment—‘Here's a problem that none of us can tackle alone. The goal is worth it, this kind of investment is needed.’”

The goal of modeling work at CISM is threefold: to support science, to supply forecasting tools, and to develop teaching tools. From the beginning, Hughes saw this as a natural fit with the integrated STC goals of scientific research, knowledge transfer, and education.

“We're an STC that's known even before we wrote the proposal what we wanted to do. That doesn't make the task any easier,” he laughs, “but at least it was clear.”

It's a balancing act to divide his time on science, education, and center management, says Hughes. “It's still a bigger management task than we thought, and we're coming to grips with that.”

Executive director Jack Quinn points out, “there's a certain energy overhead in centers, but that's part of working together in a team. That's true in industry, true in engineering projects, it's true in building hardware—there's always that overhead. So the goal has to be worth that.”



CISM executive director Jack Quinn