Space weather

—by Marc Kaufman

With thousands of satellites orbiting Earth, astronauts living in the international space station and perhaps venturing later to the moon and Mars, and with nations utterly dependent on space-based assets for their communications, navigation and spying, those responsible for the safety of all these moving parts need to know about a whole new world of weather conditions.

How are the solar winds blowing? Are very-high-energy particles from eruptions or flares on the sun heading toward Earth? Will related geomagnetic storms disrupt Earth's magnetic field? Might X-rays from the sun cause radio blackouts?

These questions and more must constantly be answered to keep astronauts safe, to keep essential satellites from having their computer memories and power systems fried, and to prevent damaging surges in Earth's elaborate electric grids.

We are still in the early stages of understanding and predicting these solar conditions, but nonetheless the era of "space weather" is here. Keeping pace with space weather developments is the National Oceanic and Atmospheric Administration at its space weather bureau in Colorado.

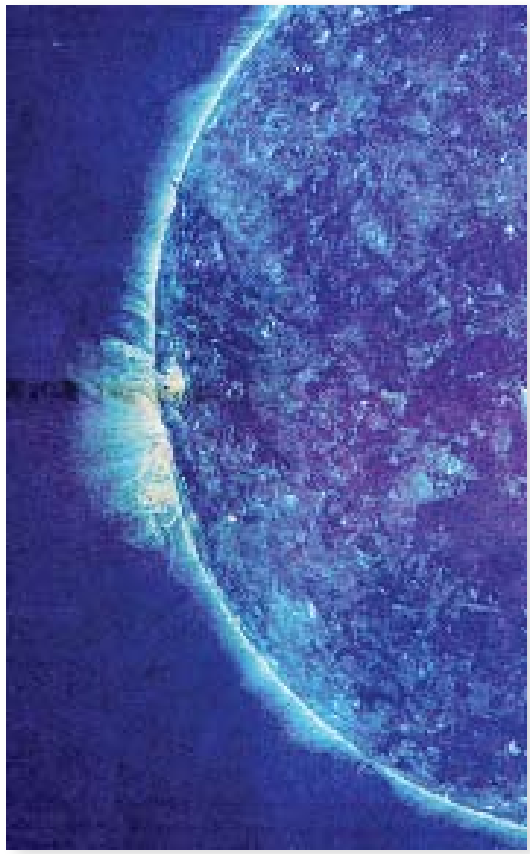
The effort to improve space weather capabilities took a major step forward last in February 2007 with the transmission of never-before-seen images of a solar eruption traveling the 93 million miles from the sun to Earth.

Sent back by the twin satellites of NASA's newly launched Solar Terrestrial Relations Observatory (STEREO), the video is part of an ambitious new effort to learn more about massive electromagnetic storms on the sun, and the dynamics and characteristics of their eruptions. The sun is a huge furnace of nuclear fusion, in constant turmoil with flares, eruptions, convections and the release of lower-energy solar winds.

The "fronts" produced by coronal mass ejections, as the biggest eruptions are called, are the prime movers of space weather in Earth's neighborhood, and understanding them better is essential to space weather forecasting.

"With STEREO, we can track the front from the sun all the way to Earth and forecast its arrival within a couple hours," said Russell Howard, principal investigator for STEREO's most cutting-edge instrument, which will allow researchers to observe the movements of solar eruptions in three dimensions. "The new views from STEREO are like having a curtain lift from our eyes—they are extraordinarily instructive."

Other satellites have studied the sun and sent back images of solar eruptions, but none with the sophistication that STEREO offers. Because the effort involves two satellites that will gradually draw apart from each other as they orbit the sun, researchers will be able to measure the eruptions much better and understand what happens as billions of tons of solar matter rush toward Earth and beyond. And because STEREO carries two unique very-wide-angle lenses, scientists will be able to watch the movement of the eruptions and their magnetic fields all the way from the sun to Earth.



A close up of the Sun in extreme ultraviolet light taken by STEREO's Extreme Ultraviolet Imager. (NASA/NRL)

The ejections that can cause hazardous space weather close to Earth are caused by the buildup and sudden release of magnetic stress on the sun's surface, above and between the turbulent regions called sunspots. The sunspots are either negatively or positively charged, and huge electromagnetic loops, much larger than Earth, form between them. Million-degree plasma—made up of highly charged hydrogen, helium and heavier elements such as iron in a state of matter that is neither solid, liquid nor gas—spews out when the arc breaks under the pressure and heads into space, initially traveling at a rate of several million miles per hour.

The sun has 11-year cycles of greater or lesser eruption activity. The front edge of a solar eruption usually takes two to three days to reach Earth, and scientists using existing technology can predict when one will arrive with an accuracy of plus or minus 12 hours. With STEREO, they hope to cut that to three hours.

The difference has enormous practical importance—astronauts on the moon, for instance, would not have to seek shelter from the blasts of high-energy radiation for nearly as long, and satellite operators could turn off their most sensitive equipment for just several hours rather than a full day.

Like most researchers, STEREO team members say they are looking for solar surprises as much as confirmation of existing hypotheses. The detailed study of space weather is in its infancy, they said, and the opportunity for discovery is vast.

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